Book: Strategic nuclear missile weapons

Introduction

The history of the use of missiles in military affairs goes back several centuries. It is now recognized that the rocket was invented in China. In Europe, from the end of the 14th century, missiles began to be used for military purposes in Italy, and then in France. The earliest known mentions of the use of missiles on the territory of the USSR date back to 1516 (near Belgorod) and in Russia - to 1675 (Ustyug). However, due to their low combat properties, their use was limited. They were a cardboard sleeve, in the upper part of which there was a payload - a warhead, usually an incendiary action. The remaining part was occupied by the rocket chamber with gunpowder, which was also a combustion chamber. To stabilize the rocket in flight, a wooden rod was attached to the sleeve, which, when exposed to the oncoming air flow, ensured that a certain position of the longitudinal axis was maintained.

In the 16th–17th centuries, many European countries developed more advanced rocket designs and gunpowder formulations. The most significant information about composite rockets, rocket units and rockets with a delta-shaped stabilizer is given in the manuscript of K. Haas (mid-16th century). In 1668, the first tests of rockets, large at that time, with launch masses of 22.6 and 54.4 kg, were carried out in Germany. Their scope of application is expanding, production is being organized.

At the end of the 18th century, interest in military missiles increased sharply. The transition to mass armies and new tactics created a need to find new means of struggle. In 1804–1913, powder rockets with a launch mass of 10 and 14.5 kg and a flight range of 3100 and 2700 m, respectively, were tested and adopted in Great Britain. In France, in 1814, a whole series of missiles weighing from 3.3 to 18.8 kg, equipped with warheads for various purposes: incendiary, shrapnel, grenade, was adopted. The design of the rockets has become a little more advanced. The paper case was replaced with a metal one.

In Russia, the development of military missiles at the beginning of the 19th century. associated with the names of I. Kartmazov, A. D. Zasyadko, K. I. Konstantinov. Zasyadko outlined the result of his work in his work "On the Matter of Incendiary and Rebound Missiles" (1817) - the first fairly complete manual on the production and combat use of missiles in Russia. According to his design, a factory for the mass production of rockets was built in 1820. A little later, combat units armed with portable missile launchers were deployed. Soon they had to participate in battles. Thus, during the Caucasian War, the Russian army made extensive use of missile weapons.

The advent of rifled artillery in the second half of the 19th century displaced rockets from arsenals. But the search for ways to improve the design, increase the flight range and accuracy of fire continued. Russian designers and inventors began to work on the possibility

application of the principle of jet propulsion to aircraft. N.I. Kibalchich's project was essentially the first in Russia in which the lifting force was created using a powder rocket engine, the action of which did not depend on the composition of the environment. At the beginning of the 20th century, the Russian scientist and inventor K. E. Tsiolkovsky scientifically substantiated the reality of the technical implementation of space flights using rockets, indicated the ways of development of rocket science, and gave diagrams of liquid rockets and liquid rocket engines.

After the end of the First World War, work began in the USSR and Germany to create new models of rocket technology. In the Soviet Union, specialized research institutions were opened: the "Gas Dynamic Laboratory VNIK at the USSR RVS" and GIRD, which in 1933 were reorganized into the Jet Research Institute, the main task of which was the creation of combat missiles. I.T. Kleimenov was appointed director of the RNII.

were put into service. At the same time, work began on the creation of ground-based launchers for the same missiles. After a series of tests, a self-propelled unit suitable for use in military conditions was developed on the chassis of a three-axle ZIS-6 off-road vehicle.

A rocket-propelled mortar was created in Germany and was widely used during World War II. The Americans and the British joined in the creation of aviation solid-fuel missiles. From the second half of 1942, such missiles were used in ever-increasing quantities. In 1944, a new class of missiles was born - ballistic guided missiles, the main target of which was objects of a strategic or operational-strategic nature. After the end of World War II, they, like all other classes of missiles, developed rapidly. Our story is about the ballistic missiles of this family that have been put into service.

List of accepted abbreviations

BB - warhead of a multiple warhead
DBK - combat missile system
BR - ballistic missile
SLBM - submarine-launched ballistic missile
MRBM - medium-range ballistic missile
GSP - gyro-stabilized platform
MS - head part
DU - propulsion system
LRE - liquid rocket engine
KB - design bureau
KVO - circular probable deviation
KRK - shipborne missile system
ICBM - intercontinental ballistic missile
UDMH - unsymmetrical dimethylhydrazine
SALT - Strategic Arms Limitation
PGS - rocket pneumatic hydraulic system
PL - submarine
SSBN - nuclear-powered ballistic missile submarine
PU - launcher
Strategic Missile Forces - Strategic Missile Forces
MIRV - multiple warhead
RD - rocket engine
Solid propellant rocket engine - solid fuel rocket engine
RK - missile system
RKS - apparent velocity control system
SAC - Strategic Air Command
SU - control system
START - strategic offensive weapons
SNF - strategic nuclear forces
TNA - turbopump unit
BTsVK - on-board digital computing complex
ShPU - silo launcher

Explanations of basic terms and concepts

YEAR OF SSBN GOING ON COMBAT PATROL - the year the SSBN went on combat patrol at sea after construction or factory repair

YEAR OF COMPLETION OF ROCKET DEVELOPMENT - the year of completion of flight tests of the rocket after developmental development

YEAR OF COMPLETION OF ROCKET MODERNIZATION - the year of completion of work on the modernization of the first rocket

YEAR OF ADOPTION OF THE SEA-BASED ROK - the year the lead SSBN with missiles of this type on board went on first patrol

YEAR OF ACCEPTANCE OF GROUND-BASED ROK into service - the year the first group of missiles of this type was placed on combat duty as a combat unit (for example, a detachment of Minuteman missiles)

SHIP-BASED MISSILE COMPLEX WITH A BR - a set of technically and functionally interconnected launchers with a ballistic missile, command and control equipment, maintenance systems and other equipment of a ship-based missile system intended for storage, ensuring launch readiness, preparation and launch of ballistic missiles

CIRCULAR PROBABLE DEVIATION - the radius of a circle centered at the aiming point, the probability of hitting which is 0.5

MAXIMUM FIREING RANGE BR - the flight range provided by the BR main engines, when using an energetically optimal trajectory, characterizes the carrier’s capabilities to deliver a given payload mass

MIRV is a multiple warhead with individually targetable warheads. MIRV type MIRV is also called the combat stage of the ballistic missile

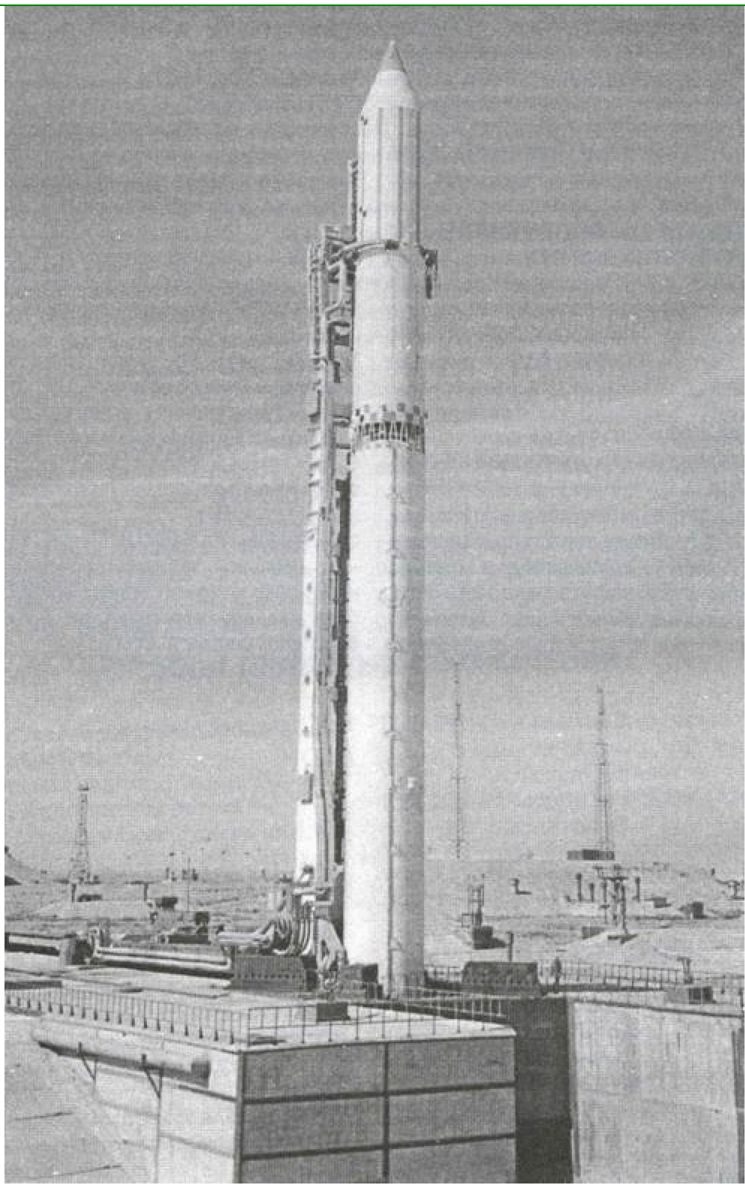
MRE - multiple warhead with dispersion (dispersion) of the warhead relative to the missile aiming point without individual targeting of each unit.

BR LAUNCH MASS - own mass (weight) of a fully loaded rocket at the moment of launch

DEGREE OF PROTECTION OF THE silo - the maximum value of the pressure drop in the front of the shock wave of a nuclear explosion, at which the combat effectiveness of the missile is preserved with a probability of 0.9

Chapter 1. General information

What is a ballistic missile



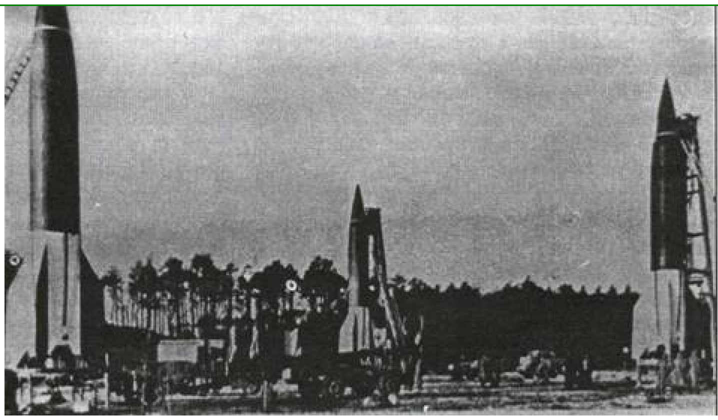
Space rocket complex "ZENIT"

Ballistic missiles (in the 50s the term "ballistic projectiles" was used) are those missiles whose flight trajectory (with the exception of the initial section that the missile passes with the engine running) is the trajectory of a freely thrown body. After the engine is turned off, the rocket is not controlled and moves like a conventional artillery shell, and its trajectory depends only on gravity and aerodynamic forces and represents the so-called "ballistic curve".

Ballistic missiles are typically launched vertically upward or at angles close to 90 degrees, which necessitates the use of a control system to place the missile on its intended trajectory to hit the target.

In order for a ballistic missile to fly hundreds and thousands of kilometers, it must be given a very high flight speed. However, even under this condition, it would be impossible to obtain a greater range if the rocket were flying in dense layers of the atmosphere. Air resistance would quickly dampen its speed. Therefore, strategic ballistic missiles spend the main part of their trajectory at a very high altitude, where the air density is low, i.e., practically in airless space.

Vertical launch of a rocket allows you to reduce the time of its movement in dense layers of the atmosphere and thereby reduce the energy consumption to overcome the force of air resistance. After a few seconds of vertical ascent, the rocket's trajectory bends towards the target and becomes inclined. Due to the operation of the engine, the speed of the rocket continuously increases until the fuel is completely consumed or the engine is turned off (cut). From this moment until it falls to the ground, the rocket moves along the trajectory of a freely thrown body. Thus, the trajectory of a ballistic missile has two sections: active - from the start of take-off until the engines stop working, and passive - from the moment the engines stop working until reaching the surface of the earth.



A-4 missiles at the launch position

The active section can in turn be divided into segments. A long-range ballistic missile is launched vertically from a launcher and travels straight upward within a few seconds. This part of the flight is called the starting part. Next, the rocket is launched onto its trajectory. The rocket deviates from the vertical and, describing an arc in the launch section, reaches the last inclined section (switch-off section), where the engines are cut off. The further trajectory of its flight is determined by the kinetic energy stored in the active section and can be accurately calculated.

Having described an elliptical arc outside the atmosphere, the ballistic missile or the separated warhead re-enters the atmosphere, having practically the same kinetic energy and the same angle of inclination of the trajectory to the horizon as when leaving it.

After this, the last stage of the passive part of the movement begins - an oblique fall in the atmosphere, accompanied by some loss of kinetic energy and very significant heating.

The first ballistic missiles

In the early 30s in the Soviet Union, specialists from the GIRD (Jet Propulsion Research Group) and the Leningrad State Gas Dynamics Laboratory dealt with the creation of liquid-fueled ballistic missiles. A prominent role in these works was played by F. A. Tsander, S. P. Korolev, M. K. Tikhonravov, Yu. A. Pobedonostsev. The main theme of the work was the creation of a liquid fuel rocket capable of solving the problems of outer space exploration. But at that time it was impossible to implement this idea from the technical side, despite some success in creating liquid fuel engines (OR-2, ORM-1, ORM-2) designed by Zander and Glushko.

The work was carried out with great stress. But it was not possible to create a combat rocket using liquid fuel before the start of the Great Patriotic War, which was greatly facilitated by repression among leading rocket specialists.

Intensive work on the creation of liquid fuel rockets was also carried out in Germany. With Hitler's rise to power, missiles took on a clearly military orientation. An army missile test site was created, located in the interests of maintaining strict secrecy of work in the center of Germany - in Kumersdorf. However, it soon became clear that the test site did not allow for flight testing of missiles. In 1936, a new army research center was created in Peenemünde, located on the islands of Usedom (near the Stetin Strait) and Greifswalder Oie (east of the island of Rügen in the Baltic Sea). From the beginning of 1937, it was headed by technical director Wernher von Braun, and in total about 15 thousand people worked at the center.

Already in the fall of 1938, the first launches of liquid fuel rockets took place. All test launches were carried out towards Sweden. The flight of the missiles was monitored by radar. By the beginning of World War II, German designers managed to create a successful rocket with liquid fuel engines, the A-3, whose flight range was 17 km. Its design was taken as the basis for the development of a more advanced rocket, which was given the designation A-4.

After a series of various tests on stands, on June 13, 1942, the first launch of the A-4 rocket took place, which ended in failure. The second launch (08/16/42) ended with a rocket explosion. On October 3, 1942, the third launch was carried out, which was considered successful. The rocket flew 190 km. They hastened to report this to Hitler, who gave instructions to take it into service under the name V-2.

The A-4 missile was a single-stage ballistic missile with a liquid-propellant jet engine powered by ethyl alcohol and liquid oxygen. The rocket body consisted of a frame with an outer skin, inside of which the fuel and oxidizer tanks were suspended. Fuel (alcohol, the reserve was 3770 kg) was supplied to the engine through a special pipeline located inside the oxidizer tank, the reserve of which reached 5000 kg.

The fuel components were supplied to the combustion chamber by a turbopump unit. Its turbine was spun by hydrogen peroxide stored in a special tank. A special starting fuel was used to ignite the main fuel. The liquid rocket engine developed a thrust of 25.4 tons at the ground. Its combustion chamber was cooled with alcohol passed through special tubes. The engine operating time fluctuated in the range of 60–65 seconds.

The missile had an autonomous software gyroscopic guidance system. It consisted of a gyrohorizon, a gyroverticant, amplification-conversion units and steering gears connected to the rocket's rudders. Four gas rudders, made of graphite and installed in the path of gases flowing from the combustion chamber, and four air rudders, which played an auxiliary role, were used as actuators of the control system. During re-entry into the atmosphere, they stabilized the rocket body. The missile was equipped with an in-flight warhead containing an explosive charge weighing 910 kg.

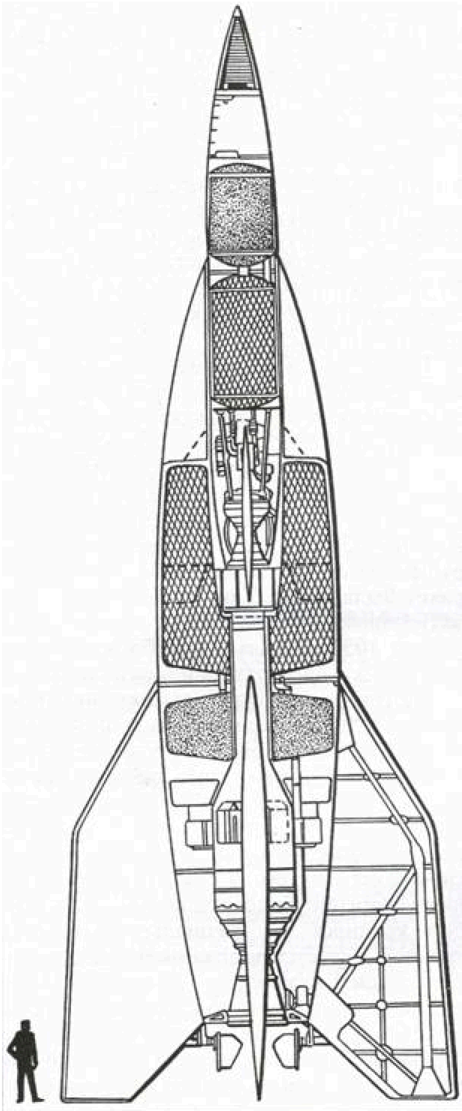
German industry quite quickly mastered the production of A-4 missiles, which made it possible to deploy combat units and subunits. Due to the low hit accuracy, a large area target was chosen for the missiles - London. The main source of errors was the gyroscopic control system itself. The fact is that it did not react to the parallel demolition of the rocket. Another source of errors was errors in the operation of the integrator - a device that determines the speed of the rocket and the moment the engine is turned off.

The first combat launch of A-4 missiles took place on September 8, 1944 from the territory of Holland. The rocket was transported to the launch site by a transporter-installer, and in total the complex of launch facilities included about 30 transport and special vehicles and units. Pre-launch preparation took almost 4 hours.

The first combat use of missiles acutely posed a problem of combating them that was practically insoluble at that time. It became clear that a new weapon had been created that could cause significant damage to the enemy. The British were never able to solve the problem of combating A-4 missiles. London could have been completely destroyed if the technical reliability of the missiles had been higher. Thus, out of 4,320 A-4 missiles launched at London, only 1,050 fell in the city. The rest either exploded upon launch or deviated from the target.

determined the lateral drift of the rocket by double integrating the lateral drift accelerations. This device was mounted on a special horizontal stabilized platform, called the "stabiplane". The platform, placed in the third ring of the gimbal, was stabilized in space by three relatively large gyroscopes, the axes of rotation of which were located perpendicular to the axes of the gimbal. The stabilization of such a site turned out to be extremely accurate.

The system for turning off the engine when the missile reached a certain speed was also improved, which significantly affected the range accuracy of the missile. Two versions of the missile speed measurement system were created: a radio command one, which used the radar method, and an autonomous method, based on the integration of the acceleration of its center of gravity. These methods were developed in Germany towards the end of World War II. Only a small number of missiles were equipped with the new control system, mainly fired at Antwerp harbor in 1945.



BR A-9/A-10 (Germany) 1944 (project)

By the end of the war, the Germans had developed several missile designs designed to fly along a gliding trajectory and having a significantly greater range compared to the A-4 missile. The missile, designated A-4B, was a cruise version of its predecessor. Its flight range was supposed to be about 600 km, and its flight time was about 17 minutes. However, the Germans were not destined to complete flight tests of this missile. In March 1945, Anglo-American aircraft almost completely destroyed the test site in Peenemünde, and Soviet troops came close to the mouth of the Oder River.

German designers also worked on two-stage missiles capable of hitting targets on the Atlantic coast of the United States. Hitler attached particular importance to these works, who dreamed of inflicting a sensitive blow on the prestige of the Americans. A project was developed for a two-stage A-9/A-10 missile, the first stage of which was a powerful A-10 starting engine, and the second was one of the cruise variants of the A-4 missile, designated A-9. It was assumed that when moving along a gliding trajectory, the rocket would be able to fly a distance of up to 4800 km. The total flight time of the rocket at this range should have been approximately 45 minutes. This missile was not tested in flight, but fire tests of the A-10 booster were completed. In general, it should be recognized that by the end of World War II, the Germans had a modern rocket industry, experienced personnel of rocket designers and rockets, the development of which promised success in the future.

The battles of the final period of the war in Europe were still raging, when the leaders of the allied countries in the anti-Hitler coalition, who appreciated the capabilities of missile weapons, instructed their military to create special teams, the main task of which was to hunt for German missile secrets.

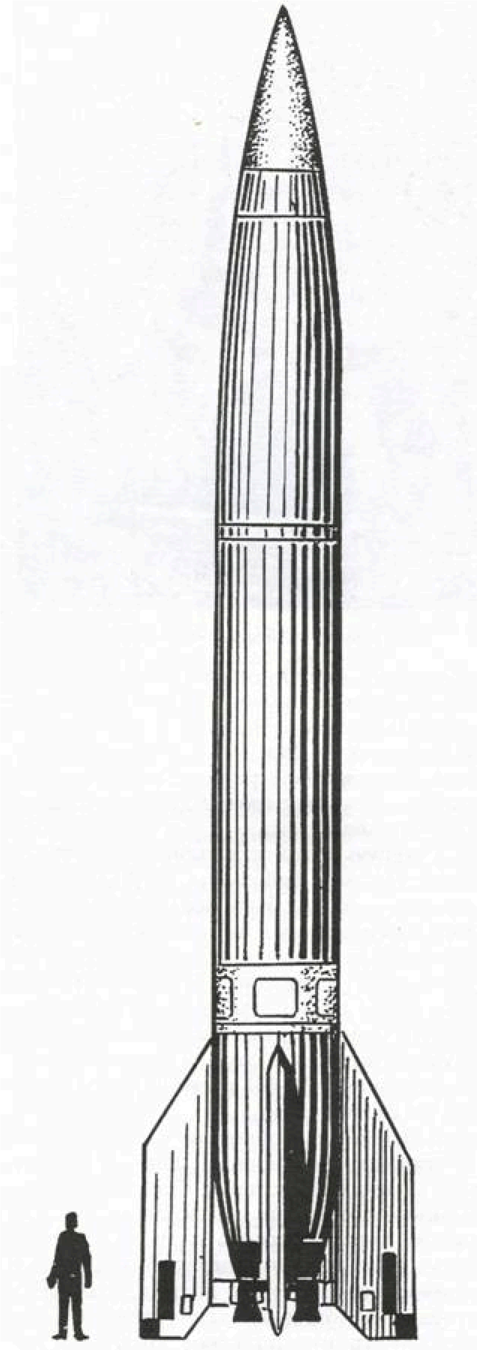
The German rocket scientists, judging that they could be useful to their new owners, began to move over to the American side. At the same time, they handed over technical and design documentation to them, and at the same time finished missiles. After the end of hostilities in Europe, the Americans removed from the area of the city of Nordhausen (this territory of Germany was supposed to be occupied by Soviet troops under the terms of the Potsdam Conference), where the Mittelwerk underground plant for assembling missiles was located, to their

The Soviet special group was headed by S.P. Korolev, who was released from prison. On this occasion he was awarded the military rank of colonel. After inspecting the ruins of a missile test site and assembly plants, the team was able to assemble mostly scattered missile parts. Later, in August 1946, a Soviet rocket institute, designated Nordhausen, operated in Germany, studying the German rocket heritage (closed in March 1947).

On the basis of the Kalinin plant, located in Kaliningrad near Moscow, a parent organization for the development of liquid fuel missiles was created - State Research Institute of Missile Weapons No. 88. Within its framework, a special design bureau was created, consisting of thematic departments (the department for the design of long-range missiles was headed by S.P. Korolev), pilot plant and scientific departments: departments of materials science, engines, fuel, aerodynamics, etc.

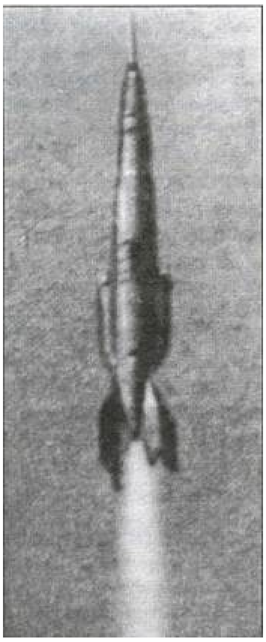
Together with NII-88, a number of newly created or repurposed enterprises in the country were involved in the development of rocket technology. To coordinate all work, the State Committee on Rocket Technology was created. The head of state, J.V. Stalin, also paid great attention to the missile problem.

The designers were faced with the task of quickly creating their own rocket based on German developments. She was assigned the index P-1. 35 research institutes and design bureaus, 18 factories directly participated in the creation of the first rocket. Considering that most of them had different departmental subordination, S.P. Korolev created the Council of Chief Designers to promptly resolve all fundamental scientific and technical issues. Its members included V. Glushko, V. Barmin, V. Kuznetsov, N. Pilyugin, M. Ryazansky. In the difficult conditions of post-war devastation, the designers managed to quickly prepare the rocket for testing.



BR R-2 (USSR) 1951

R-2 rocket at the moment of launch



R-2A rocket in flight

The main difficulty was caused by the propulsion system. Work on liquid propellant engines for long-range missiles was entrusted to OKB-456, formed in July 1944 at aircraft plant No. 16 in Kazan, to a team of designers led by V. Glushko. Within one year, they managed to reproduce the design of the A-4 (RD-100) rocket engine. And a year later they created an accelerated modification of the RD-101 with a thrust of 35 tons, and then the RD-103 with a thrust of 44 tons.

75% ethyl alcohol was used as fuel, and liquid oxygen was used as an oxidizer. Fuel was also used to cool the propulsion system. To operate the turbopump unit, two components were used: hydrogen peroxide and a solution of sodium permanganate, which significantly complicated the operation of the rocket. Structurally, the single-stage R-1 rocket consisted of a head section, an instrument compartment with control system instruments, middle and tail sections. The supply of fuel components provided a maximum flight range of 270 km.

The development of the control system was entrusted to the design team of NII-885 under the leadership of Pilyugin, radio engineering control and measurement systems - to the team under the leadership of M. Ryazansky, a set of command devices - to the division of the chief designer V. Kuznetsov, who was part of the MNII-1 of the USSR Ministry of Shipbuilding Industry.

The rocket used an autonomous control system. The main devices were grouped in two machines - stabilization and range control. A gyrohorizon and a gyroverticant were used as sensitive control devices, and gas-jet rudders made of graphite were used as executive bodies. Additional stability was provided by tail fins. The missile had a warhead that did not separate in flight, equipped with a conventional explosive weighing 785 kg. The launch weight of the rocket reached 13.4 tons.

To conduct flight tests, the 4th State Central Test Site was created in the area of the village of Kapustin Yar, the first head of which was Lieutenant General V. Voznyuk. It was there that on October 10, 1948, the R-1 rocket was successfully launched, completely manufactured according to its own drawings at Soviet factories from domestic materials. In the first series of flight tests of the R-1, nine missiles were launched. All flights were completed successfully.

To operate the missile system, special units were created within the armed forces - special-purpose brigades of the Reserve of the Supreme High Command. Major General of Artillery A. Tveretsky was appointed commander of the 1st brigade.

designer of the ground-based complex was V. Barmin.

However, it was clear to everyone that the R-1 rocket needed to be improved. What was required was a weapon capable of hitting targets throughout the entire operational depth of the enemy's defense. The design, testing and operation experience gained during the creation of the R-1 rocket served as the basis for further development of the design. The R-2 rocket, developed under the leadership of S.P. Korolev, externally differed from it only in its increased size. However, in terms of combat properties and design solutions, it was significantly more advanced than its predecessor.

The R-2 had a sealed instrument compartment carrying a fuel tank and a head section that could be separated after the fuel burned out. The rocket was equipped with an RD-101 liquid-propellant rocket engine (modification of RD-100) with a thrust of 37 tons. The engine ran on liquid oxygen and 92 percent ethyl alcohol. The control system was supplemented with a lateral radio correction system, which significantly reduced the directional dispersion of the impact points of the warheads. The flight range of the R-2 missile reached 600 km. It carried a combat charge weighing 1008 kg.

After a series of flight tests conducted at the Kapustin Yar test site, on November 27, 1951, the missile system with the R-2 missile was put into service. To operate the new RK, four RVGK brigades were created, called engineering brigades.

S.P. Korolev thought not only about the military use of missiles. In 1949–1955, on the basis of the R-1 rocket, a series of geophysical rockets R-1 A, (B, B, D, E) was created. The rockets were intended to study the upper layers of the atmosphere according to the USSR Academy of Sciences program. On May 25, 1949, the first flight of the R-1 A rocket took place, on which two containers with research equipment detachable at altitude were installed. The containers were equipped with parachutes that opened at an altitude of 20 km. A total of 18 successful launches were carried out. Due to the improvement of rockets of this series, the payload increased from 170 kg on the first rocket to 1160–1819 kg on subsequent modifications.

In 1954, on the basis of the R-2 rocket, the R-2A geophysical rocket was created. In 1957–1960, 11 successful launches of R-2A rockets were carried out at altitudes of about 200 km in order to study the chemical composition and pressure of the atmosphere, as well as the vital activity of animals, which were launched in sealed containers. Although the combat value of the R-1 and R-2 missiles was not high, they played a significant role in the development of rocket science in the USSR.

What did the Americans do with the German missile legacy they inherited? Initial interest was quickly satisfied. We tested the removed missiles and were convinced of their low capabilities.

And since military experts did not find any use for them, it was decided not to produce these missiles. In addition, American politicians and military leaders relied on monopoly possession of a nuclear bomb. Most of the budget allocated to the Pentagon was used to finance programs to build new B-36 and B-50 strategic bombers, capable of delivering a bomb load of tens of tons over thousands of kilometers. They were also carriers of nuclear weapons.

Redstone rocket at launch

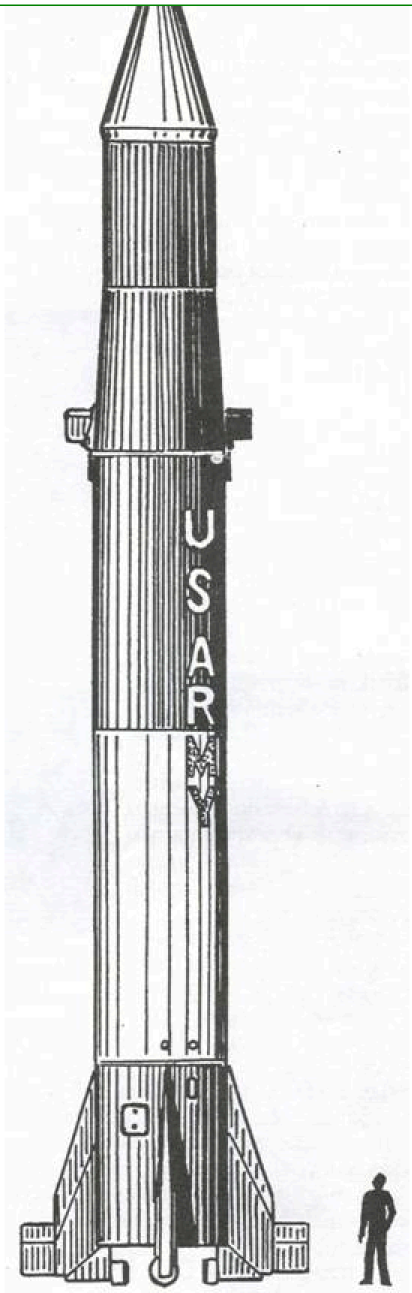
But already in 1950, at the height of the Korean War, American military minds were forced to remember missiles. This decision was caused by the large losses of strategic bombers from the fire of the Soviet MiG-15.

That's when the German rocket scientists came in handy. In 1950, Wernher von Braun and his team of 130 engineers, as well as 500 American personnel and several hundred workers, began intensive work to improve the design of the A-4 rocket with a range of 800 km. The missile center settled in the city of Fort Bliss at the Redstone arsenal.

Orders for missiles soon followed. In 1951, the US Army command ordered a missile suitable for use in military units. The missile was supposed to be mobile, carry a nuclear warhead and have a range of 200 miles (320 km).

After two years of hard work, the missile, designated M8, was presented for testing. The first launch took place on August 20, 1953 from Cape Canaveral, where the Eastern Test Range was built in 1950. After a series of launches, the rocket was transferred for military testing. For this purpose, a special military unit was formed - the 40th Field Artillery Missile Group, which conducted 36 test launches until May 1958. Finally, in May 1958, it was decided to accept the missile into service with the US Army under the name Redstone. But they decided to produce it in a small series. It entered service with the same 40th Missile Group, which was redeployed to West Germany.

Although the missile was based on the design of the German A-4, the Redstone bore little resemblance to it. She was heavier and bigger. A new A-6 engine was developed, running on liquid oxygen and alcohol, with a turbopump supply of fuel components and a thrust cut-off system.



BR "Redstone" (USA) 1958

The flight of the rocket was controlled by an inertial control system, designed by specialists from the Ford Instrument company, with air-suspension gyroscopes. The executive bodies of the control system are the same as on the A-4—gas-jet and aerodynamic rudders.

The warhead had a nuclear charge and was separated in flight from the body after the main engine stopped working. Upon entering the dense layers of the atmosphere, its flight was controlled by wedge-shaped rudders located on the rear skirt of the head housing.

The missile system was placed on Chrysler vehicles. The main disadvantage of the rocket was considered to be the long pre-launch preparation time for combat use. The rocket was installed on the launch device (launch table) using a special crane. After which it was filled with fuel components, aimed and only then launched. The starting position had to be chosen taking into account the possibility of placing heavy and bulky special units. The Redstone missile played a prominent role in providing the necessary expertise to develop the next generation of ballistic missiles.

The first ballistic missiles were created to solve strategic problems, despite the fact that they had a flight range of less than 600 km (according to modern classifications adopted in NATO countries and Russia, missiles with such a flight range are classified as operational-tactical). All these missiles had common disadvantages. These include low hit accuracy and the use of low-energy fuel as fuel components.

Missile systems were considered mobile, but this rather refers to the method of transporting missiles to launch positions, since they were all launched from ground-based launchers. The long preparation time for launch, estimated at several hours, did not allow the missiles to be used against targets critical to the time of their destruction. A significant number of special equipment moving along roads in one direction allowed enemy reconnaissance to promptly warn their command about the threat of a missile attack. The technical reliability of these missiles left much to be desired.

All this predetermined their limited use in the army, with the exception of the German A-4, better known under the designation FAU-2. Nevertheless, the role of these missiles in the development of rocket technology is great. They allowed designers to test theoretical developments in this area in practice and to develop a certain groundwork for the creation of the next generation of ballistic missiles, which have become a formidable weapon. The first, most difficult, step has been taken. And it was done successfully.

Today there are many different types of rockets. Most of them are equipped with a control system that ensures flight along the required trajectory. Among guided missiles, a large group consists of ballistic missiles, the movement of which, with the exception of a relatively small section of controlled flight with operating propulsion systems, occurs along the trajectory of a freely thrown body (ballistic trajectory). This group includes operational-tactical and strategic surface-to-surface and ship-to-surface combat missiles with a flight range from hundreds to several thousand kilometers.

Based on the number of stages, rockets are divided into single-stage and composite (multistage). A single-stage ballistic missile consists of a payload (PC) and a rocket unit, generally formed from a rocket propulsion system with a fuel compartment with a supply of propellant, a fuel supply system, a control system and power structural elements. The main characteristic of a ballistic missile is the ideal speed that can be achieved at the end of the active phase of flight when moving in a straight line (outside the atmosphere and gravitational field) under the influence of only the thrust of the rocket engine.

Composite rockets can be of various design designs. There are design schemes with transverse division (rocket blocks of the stages are located sequentially along the height of the rocket and also sequentially enter into operation), with longitudinal division (the so-called batch circuit, allowing simultaneous operation of blocks of different stages) and combined, combining the features of the first two.

The design of rockets depends significantly on its purpose and the type of rocket engines used. Most modern military missiles are equipped with solid propellant rocket engines. Rockets of earlier developments are characterized by liquid-propellant engines with pumped fuel supply, including afterburning of the generator gas that rotates the turbine of the turbopump unit. The rocket blocks of the first stages of rockets are characterized by multi-chamber rocket engines, which have one common powerful pump for two or four combustion chambers, which makes it possible to reduce the height of the propulsion system.

The main power elements of the rocket design are made in the form of thin-walled shells made of high-strength light alloys or composite materials. In a rocket unit with a liquid propellant engine, most of the volume is occupied by the fuel compartment with liquid rocket fuel, consisting of tanks with oxidizer and fuel. The tanks are connected to the liquid-propellant rocket engine by main pipelines and are equipped with devices for filling and draining components and monitoring their level. Baffles can be installed in the tanks to dampen longitudinal and transverse vibrations of the fuel during flight.

The most economical and widespread is the power scheme of the fuel compartment with load-bearing tanks, the walls of which simultaneously serve as the shell of the rocket body. By creating a relatively small internal boost pressure in such tanks, it is possible to eliminate the loss of stability, which is dangerous for thin-walled shells, and at the same time promote cavitation-free operation of the pumps. The length of the fuel compartment is somewhat reduced if it is made in the form of a single shell, the volume of which is divided into cavities of fuel and oxidizer by a sealed partition. To stabilize the rocket, an intermediate baffle can bisect a cavity occupied by the same component, with the component first being consumed from the bottom of the tank and then from the top.

In the scheme of a fuel compartment with suspended tanks (which can have a cylindrical, spherical, torus-shaped or other more complex shape), they are attached by power units to the supporting body. Such a body is also connected to other compartments by end frames. The tail compartment, which houses the liquid propellant engine and some elements of the fuel supply system fittings, has a similar design.

The separation of rocket blocks can occur both before the liquid rocket engine of the next stage block is turned on by braking the block of the previous stage with auxiliary rocket engines ("cold" division), and with the rocket engine running in the thrust decline section ("hot" division).

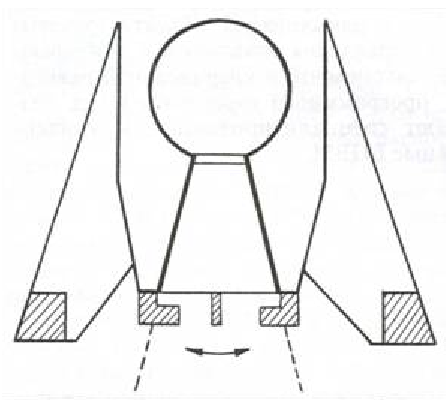
Control of the thrust vector of modern liquid-propellant rocket engines, necessary for the flight of a rocket according to a given program, is carried out by rotating the rocket engine chamber using low-thrust control rocket engines, blowing part of the gas beyond the critical part of the nozzle and other methods. In the case of a multi-chamber remote control, the control torque can also be created by mismatching the thrust of the fixed chambers, the thrust of each of which is adjusted within certain limits.

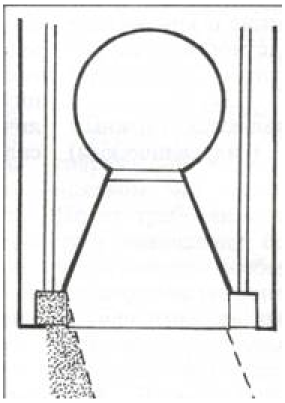
In a rocket unit with a solid propellant rocket motor, the role of a fuel compartment with a supply of solid fuel is performed by the rocket motor body, and the tail compartment houses the nozzle block and equipment necessary to control the thrust vector. Control is carried out either by turning one or more nozzles, or by lateral injection of gas into the main flow of combustion products in the area of the expanding part of the nozzle, which leads to gas-dynamic asymmetry of the flow and redistribution of pressure on the walls of the bell, creating a resulting control torque relative to the center of mass of the rocket.

The thrust developed by the solid propellant rocket engine is transmitted to subsequent compartments or rocket units (in a composite cross-fission rocket) using a transition rod truss or a shell reinforced with stringers. In order to be able to turn off the thruster before the fuel burns out completely and to separate the solid propellant rocket body from the head of the combat missile, inclined reverse thrust nozzles can be provided on its front bottom. When a certain combination of flight speed, its direction and the coordinates of the rocket is reached, following a special command from the control system, these nozzles open and direct the gas flow from the combustion chamber through the front bottom of the body, creating reverse thrust that ensures separation.

The missile control system is designed to obtain motion parameters at the final point of the launch site necessary to complete the mission assigned to the missile. At the same time, the control system must provide a solution to the problem of motion stability and reduction of external loads on the rocket body. In the simplest case, the missile launch trajectory is set in advance. In a more complex one, a terminal control system is used, which does not lead the trajectory to a given one, but allows significant deviations from it, making sure, however, that the kinematic parameters at the end of the active section are calculated. The latter method requires the use of powerful digital computers.

Methods for obtaining control forces

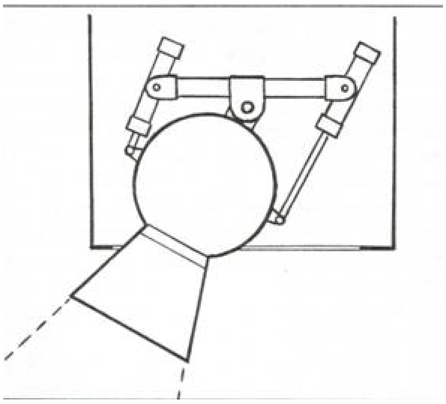




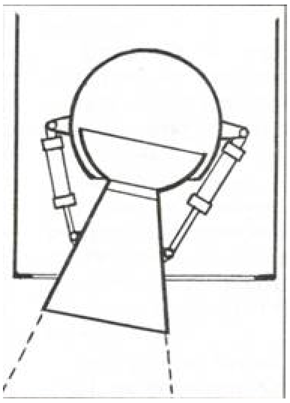
Method of injection into the supercritical part of a liquid gas nozzle

Strategic nuclear missile weapons

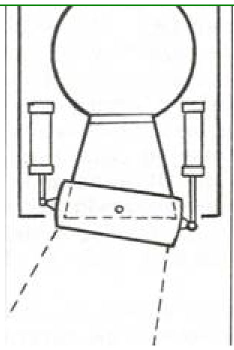
Application of gas exhaust plates



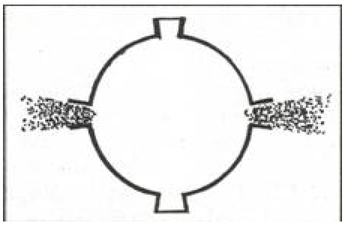
Combustion chamber rotation



Application of deflectable combustion chamber nozzle



Application of control nozzle deflector



Application of vernier or jet engines

The control system consists of sensors, converting devices and steering gears. Gyroscopic stabilized platforms are usually used as sensors, keeping their position relative to the fixed stars unchanged and allowing one to measure the angles of deflection of the rocket body relative to the coordinate system associated with such platforms. The GPS is equipped with devices that respond to linear accelerations in the longitudinal and two transverse directions. By integrating the required number of times the signals taken from these instruments, it is possible to obtain a complete picture of the kinematics of the rocket's movement, in particular about the speeds and drifts in directions transverse to the trajectory.

Steering machines are complex electromechanical (hydraulic) drives for turning the main taxiway or special steering taxiways in accordance with signals generated by converting devices. In addition to the main tasks, the control system also performs other functions: supplying power to the necessary devices, program-logical control of the operation of rocket systems during preparation and launch of the rocket, arming fuses. The high demands placed on the reliability of the control system lead to the need for duplication and redundancy of the most critical control loops.

The on-board digital computer ensures the operation of the control system. It is designed to solve on board a moving object (rocket) the problems of motion control and stabilization, autonomous and inertial navigation, program control, etc. There are specialized and universal onboard computers.

Chapter 2. Medium-range ballistic missiles

The accumulated experience in creating the first military ballistic missiles allowed designers to begin designing missiles with an increased range. Soviet rocket scientists were the first to begin this work. Immediately after the completion of work on the R-2 rocket, the government in 1952 received an order to design a rocket with a flight range of more than 1000 km. The task was assigned to TsKB-1. Already in 1953, the rocket, designated R-5, was presented for flight tests, which were carried out at the Kapustin Yar test site.

The tests were carried out with varying degrees of success. Despite all the difficulties, the development of the rocket continued. The R-5 was a single-stage rocket engine powered by liquid oxygen (oxidizer) and 92 percent ethyl alcohol (fuel). An improved rocket engine from the R-2 rocket, designated RD-103, was used as a propulsion engine. It was made single-chamber, with a TNA driven by products of the catalytic decomposition of concentrated hydrogen peroxide in a gas generator. The engine had an improved cooling system for the combustion chamber heads and nozzles. Bellows pipelines for the oxidizer and elastic ones for fuel were introduced, a centrifugal pump was installed to supply hydrogen peroxide, and the overall layout was improved. All systems and elements of the rocket engine have undergone changes. All this made it possible to increase the engine thrust on the ground to 41 tons, while the overall height of the engine decreased by 0.5 m, and its weight decreased by 50 kg.

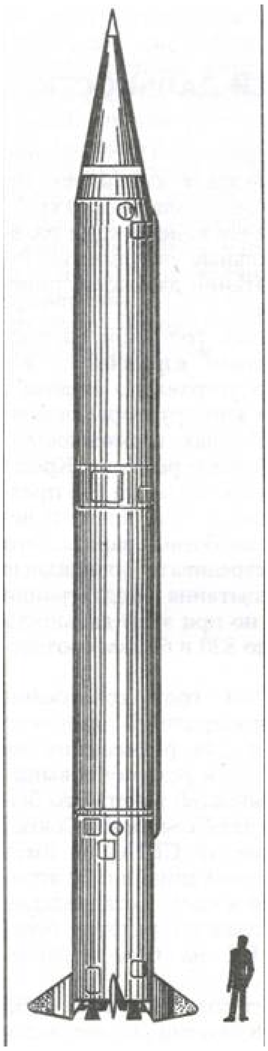
Improvements in the design of the rocket have yielded positive results. During flight tests, the flight range reached 1200 km.

The missile was equipped with a warhead loaded with a conventional explosive, which did not suit the military much. At their request, the designers were looking for ways to increase combat capabilities. An unusual solution was found. In addition to the standard warhead, it was proposed to attach two, and a little later, four additional warheads to the R-5. This would make it possible to fire at area targets. Flight tests confirmed the viability of the idea, but at the same time the flight range was reduced to 820 and 600 km, respectively.

The creation in 1953 by Soviet nuclear scientists of a small-sized nuclear charge suitable for placement on missiles opened the way to a sharp increase in the combat capabilities of missiles. This was especially important for the Soviet Union, which, unlike the United States, did not have powerful strategic aviation. On April 10, 1954, a government decree was issued on the creation of a rocket equipped with a nuclear warhead based on the tested R-5.

Less than a year later, on January 20, 1955, the first test launch of the R-5M rocket took place at the Kapustin Yar test site. This is the index they decided to assign to the new product. On February 2, 1956, the first launch of the R-5M, equipped with a warhead with a nuclear charge, was carried out. Despite the general excitement and the inevitable excitement in such cases, aggravated by the presence of high authorities, the combat crew worked with high professionalism. The missile launched safely and reached the target area. The automatic detonation of the nuclear charge worked reliably. By the beginning of the summer of 1956, the flight test program for the R-5M missile was completed, and on July 21, by government decree, it was adopted by the engineering brigades of the RVGK, where it remained until 1961.

The R-5M rocket had the same propulsion system with an automatic thrust control system. The control system is autonomous, with a lateral radio correction system. To increase its reliability, redundancy of the main units was provided: automatic stabilization, on-board power sources, point of impact of the warhead from the calculated aiming point was 3.7 km.



MRSD R-5M (USSR) 1956

The combat missile system with the R-5M missile was more advanced than its predecessors. The rocket launch was fully automated. During the pre-launch preparation process, all launch operations were monitored. The launch was carried out from a ground launcher (launch pad). When installing the rocket on the launch pad, it was not necessary to first load it onto the installer. But the missile system also had disadvantages. Pre-launch checks, refueling and aiming operations for the R-5M were carried out without automation equipment, which significantly increased the preparation time for launch. The use of rapidly evaporating liquid oxygen as one of the components of rocket fuel did not allow keeping the rocket fueled for more than 30 days. To produce a supply of oxygen, it was necessary to have powerful oxygen plants in the areas where the missile units were based. All this made the missile system inactive and vulnerable, which limited its use in the armed forces.

R-5 and R-5M missiles were also used for peaceful purposes as geophysical missiles. In 1956–1957, a series of rockets were created, designated R-5A, R-5B, R-5V, to study the upper layers of the atmosphere, the Earth's magnetic field, radiation from the Sun and stars, and cosmic rays. Along with the study of phenomena associated with geophysical processes, these rockets were used to conduct medical and biological research using animals. The missiles had a launchable warhead. The launch was carried out at altitudes of up to 515 km.

R-5A in flight

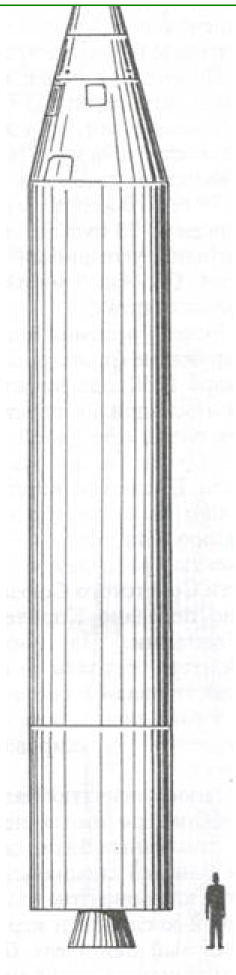
At the same time, geophysical rockets differed from combat ones not only in their head part, but also in size. Thus, the R-5A and R-5B missiles had a length of 20.75 m and a launch weight of 28.6 tons. The R-5B missile had a length of 23 m. In 1958–1977, 20 missiles of this series were successfully launched.

During the period of work on the R-5M, a split occurred in the Korolev Design Bureau. The fact is that Korolev was a supporter of the use of low-boiling rocket fuel components. But liquid oxygen, used as an oxidizer, did not allow combat missiles to achieve high combat readiness, since it was impossible to keep it in the missile tanks without loss for a long time, estimated in tens of months. However, its use on launch vehicles for space objects promised certain benefits. And Sergei Pavlovich always remembered his long-standing dream of flying into space. But he had opponents, led by the talented designer Mikhail Kuzmich Yangel. They believed that combat missiles using high-boiling fuel components were more promising. The conflict at the beginning of 1955 took on rather acute forms, which was not conducive to productive work. Since Yangel was a prominent figure in the world of rocket designers and the conflict clearly interfered with business, a wise decision was made. By government decision, a new Special Design Bureau No. 586 was created, headed by M. Yangel, which was located in Dnepropetrovsk. He was entrusted with the development of combat missiles using high-boiling rocket fuel components. So the Soviet rocket scientists had internal competition, which later played a positive role. On August 13, 1955, a government decree assigned the new design bureau the task of developing a medium-range missile equipped with a warhead with a nuclear charge.

Just at the same time, overseas they began designing ballistic missiles capable of hitting targets 3,000 km away from the launch site. In the US there was no need to create artificial competition. Everything was completely fine there. However, it was precisely this circumstance that forced American taxpayers to fork out extra cash. Financing of military orders in the US Department of Defense is carried out by branch of the armed forces (each branch has its own ministry, which is the customer of weapons models). It so happened that the Ministry of the Army and the Ministry of the Air Force issued technical specifications with almost identical characteristics for the development of MRBMs independently of each other to different companies, which ultimately led to duplication of work.

The army command entrusted the development of its missile to the Redstone arsenal. By this time, Wernher von Braun had largely completed work on the previous rocket and was able to concentrate his main efforts on the new one. The work promised to be interesting not only from a military point of view. He understood perfectly well that a rocket of this class could launch an artificial satellite into space. Thus, the dream of von Braun's youth could come true, because in the late 20s he began working on rockets with the goal of conquering outer space.

Design work progressed successfully and already in the early autumn of 1956 the rocket was transferred for testing. This was largely facilitated by the fact that when designing the rocket, designated SM-78, and even later - Jupiter, many solutions and design elements tested on the Redstone rocket were used.



IRBM "Jupiter" (USA) 1958

On September 20, 1956, a Jupiter rocket was launched from the Eastern Test Site (Metro Canaveral) to a range of 1098 km. The first launch at maximum range took place on May 31, 1957. A total of 38 launches were carried out until July 1958, of which 29 were considered successful or partially successful. There were especially many failures during the first starts.

Even before the decision to accept the missile for service (adopted in the summer of 1958), on January 15, 1958, the formation of the 864th squadron of strategic missiles began, and a little later another one, the 865th. Each squadron was armed with 30 missiles. After appropriate preparation, they were transferred to Italy and Turkey. Their missiles were aimed at targets located in the European part of the Soviet Union. Several missiles were transferred to the Royal Air Force of Great Britain. The Jupiter missiles were in service until 1963, when they were eliminated in accordance with the terms of the agreement between the USSR and the USA on the settlement of the Cuban Missile Crisis.

The single-stage Jupiter ballistic missile had load-bearing integral fuel tanks welded from large panels of a special alloy. Liquid oxygen and TR-1 kerosene were used as fuel components. The main engine was single-chamber with turbopump fuel supply. To obtain control forces, the combustion chamber was made deflectable.

In flight, the rocket was controlled by an inertial control system. To increase the accuracy of gyroscopes, special air suspensions were developed for them. The issue of controlling the rocket by its roll angle was interestingly resolved. For this purpose, a movable (fixed in a gimbal) exhaust pipe of the turbopump unit was used.

The missile was equipped with a nuclear warhead with a capacity of 1 Mt. To protect the warhead from overheating when entering the dense layers of the atmosphere in the passive part of the trajectory, it was covered with a special coating. To give the necessary speed to achieve maximum flight range, the warhead was equipped with an additional powder engine. The missile system was considered mobile. The rocket was transported on a wheeled conveyor and launched after being installed on a launch device, which had an original system of support on the ground in the form of folding petals.

The medium-range ballistic missile, developed for the US Air Force by Douglas Aircraft, received the designation SM-75. Bromberg was appointed chief designer of the missile system, and Colonel Edward Hall was appointed head of the entire program.

The first rocket was submitted for static testing in October 1956, earlier than the Jupiter rocket. The first launch of the product, which by this time was given the name "Thor," took place on January 25, 1957, a year after the start of design. The designers were in a hurry, which affected the flight characteristics of the rocket. Immediately after detachment from the launcher, it exploded. During the first half of 1957, there were four more rocket explosions and many failures during preparation for launch. These failures cost Colonel Hall his job.

The designers had to put in a lot of effort to make the rocket fly. Only in September 1957 the test launch was successful. The rocket flew 2170 km. Subsequent test launches were also successful. In the summer of 1958, a test launch took place from a mobile launcher designed for military units. In the same year, the Thor was adopted by the US Air Force.

The rocket was single-stage. Two-thirds of the body was made up of the fuel compartment, welded from large sheets of a special aluminum alloy. Liquid oxygen and kerosene were used as rocket fuel components. The rocket was equipped with a deflectable sustainer liquid rocket engine LR-79, developed by Rocketdyne, which developed a thrust on the ground of 68 tons. Its operating time was 160 seconds. The rocket engine had a height of 3.9 m.

To supply fuel components, a turbopump unit with parallel shafts was used, on one of which axial-centrifugal oxidizer and fuel pumps were installed, and on the other, an axial two-stage active turbine. A heat exchanger—a liquid oxygen evaporator—was installed at the turbine outlet. The resulting gas was used to pressurize the oxidizer tank. The ignition of the fuel components in the combustion chamber occurred from the starting fuel (triethylaluminum) contained in the sleeve, which is destroyed by the pressure of the main fuel coming from a special starting tank.

The rocket was equipped with an inertial control system from General Motors. The head of the rocket contained a nuclear charge with a power of 1.5 Mt. The maximum flight range was 3180 km.

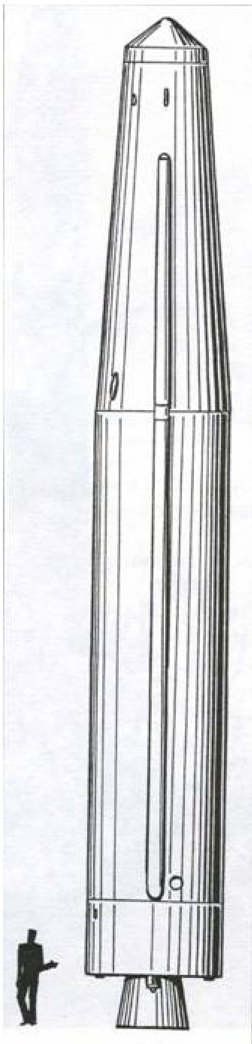
The Thor MRBM squadrons, armed with 15 missiles each, were based in Italy, Turkey and England. The rocket was convenient for transportation by transport aircraft. Some of the missiles were transferred to Great Britain in 1961, where they were placed at missile bases in Yorkshire and Suffolk. The Thor and Jupiter rockets were built in a small series. Their total number in the US Air Force and Army reached 105 units.

The Americans actively used the Thor rocket as the first stage of a whole family of launch vehicles (referred to as LB-2). It was constantly improved. Thus, the latest modification of the LB-2, used on the Tor-Delta launch vehicle, had a length of 22.9 m, a launch weight of 84.8 tons (including fuel - 79.7 tons). It was equipped with a liquid propellant engine with a thrust of 88 tons on the ground and an operating duration of 228 seconds. On the basis of the Thor rocket, the first stage of Torad was developed, which differed from the basic one in the presence of mounted launch solid propellant rocket engines.

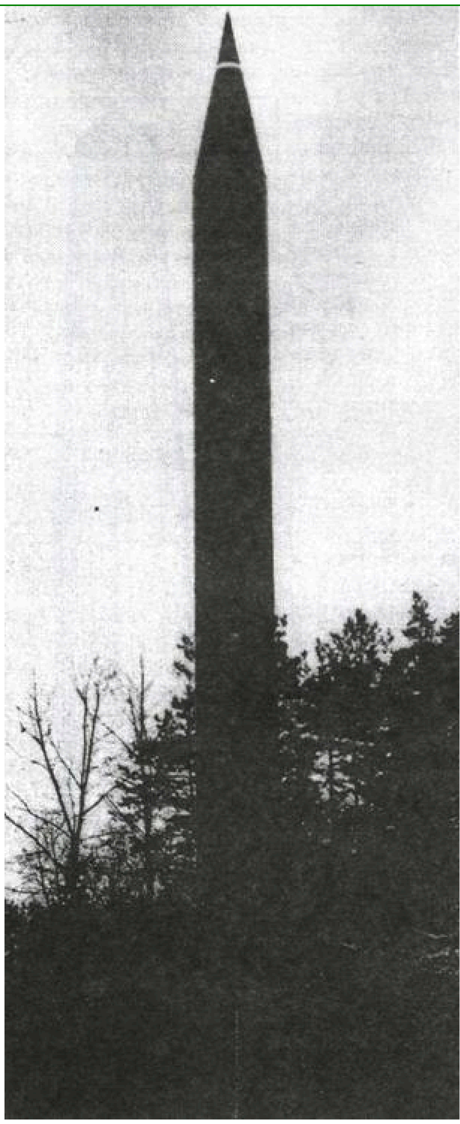
Around the same time that work on the creation of the American Thor and Jupiter MRBMs was being completed, the USSR completed flight tests of the new medium-range missile R-12, created at OKB-586 by the design team led by M. Yangel.

The first test launch of the R-12 rocket took place on June 22, 1957, almost two years after the start of design work. Flight tests took place until December 27, 1958 at the Kapustin Yar training ground. The combat missile system with the ground-based R-12 missile was put into service on March 4, 1959. The R-12 became the first Soviet combat ballistic missile with a nuclear warhead, which was produced in a large series. It was these missiles that became the main missile armament of the new branch of the USSR Armed Forces created in December 1959 - the Strategic Missile Forces.

The R-12 missile (industry designation 8K63) is single-stage, with load-bearing tanks and a liquid-fueled rocket engine. Nitric acid oxidizer and hydrocarbon fuel were used as rocket fuel components. To ignite the main fuel, special starting fuel TG-02 was used.



IRBM "Thor" (USA) 1958



MRBM R-12 at the launch position

The rocket's propulsion system consisted of a four-chamber rocket engine RD-214 with a thrust on the ground of 60 tons. Its mass was 645 kg, height 2.38 m, operating time 140 seconds. RD-214 had four chambers, a fuel pump, a gas generator, control units and other elements. Liquid rocket engine chambers have interconnected shells, with regenerative and curtain fuel cooling, with corrugated spacers between the walls. The chambers are made of steel and fastened into a rigid block, to which the TNA is attached on top on a special frame. It contains three centrifugal single-stage pumps and an axial two-stage active turbine, which are located on two coaxial shafts. An oxidizer pump and a turbine are installed on one shaft, and fuel and 80 percent hydrogen peroxide pumps to power the gas generator are installed on the other. Ignition of the fuel in the chamber is chemical, using starting fuel, poured into the line up to the main fuel valve. Engine thrust is regulated by changing the flow rate of the working fluid through the gas generator. The rocket engine is attached to the rocket using supports located in the upper part of the chambers.

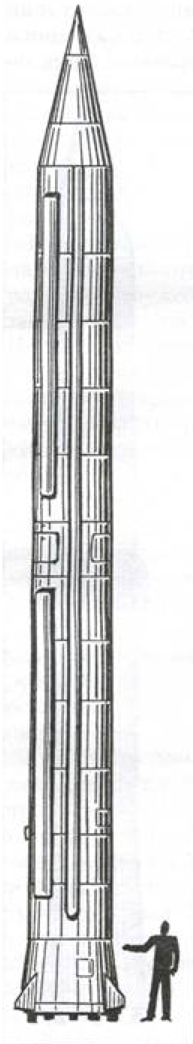
The rocket was equipped with an autonomous control system, the executive elements of which were gas-jet rudders. In order to improve the stabilization of the rocket in flight, for the first time in domestic rocket science, the oxidizer tank was divided into two parts. Additionally, the rocket was equipped with four aerodynamic fixed stabilizers. The control system included devices for normal and lateral stabilization of the center of mass, an apparent speed control system, and an automatic range control with duplication of switching channels. The control system provided a CEP of 2.3 km for the warhead impact points when flying to a maximum range of 2000 km.

The R-12 missile was launched from a ground launcher, where it was installed in an unfueled state in preparation for launch. After refueling operations and aiming, the missile was ready for launch. The total preparation time for launch reached three hours and largely depended on the level of training of combat crews. In addition, the ground complex had low survivability. Therefore, the designers of the Yangel Design Bureau were given the task of creating a ballistic missile system based on R-12 missiles in specially designed silos.

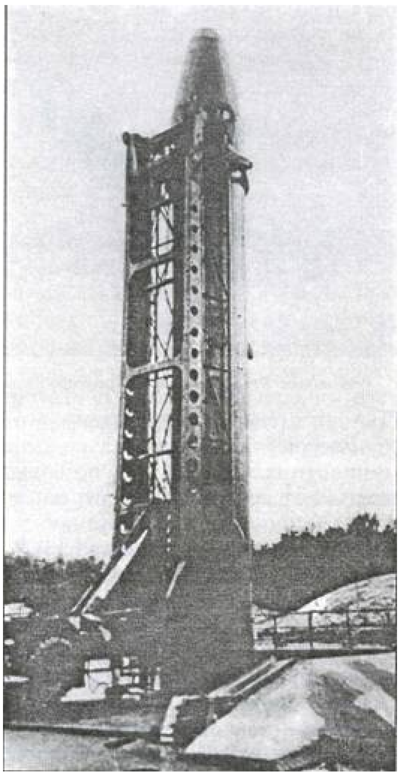
On December 30, 1961, the first launch of the modernized missile, designated R-12U, took place. Tests were carried out until October 1963 at the Kapustin Yar training ground, where special silo launchers were built, and on January 5, 1964, the BRK with the R-12U missile was put into service. The launch position of the R-12U missiles consisted of four silos and a command post.

The flight test program of the R-12 missile has not yet been completed, but it has already become clear that this missile will not be able to achieve a long flight range. In order to cover the entire medium-range range within the continental theaters of war, a new missile was needed. On July 2, 1958, the Yangel Design Bureau received a government task to design a missile with a flight range of 3,600 km and higher performance characteristics than the R-12.

The design team, which had accumulated sufficient experience by this time, was able to successfully solve the problem within two years. On July 6, 1960, the first test launch of a new missile, designated R-14, took place. Although it was considered a success, in reality not everything was smooth sailing. The first series of test launches showed that the new rocket was successful, however, the phenomenon of cavitation was noted. The designers dealt with this problem quite quickly. Flight tests were carried out at the Kapustin Yar test site until February 15, 1961, and after their successful completion, on April 24 of the same year, the BRK with the R-14 missile was adopted by the Strategic Missile Forces.



BRSD R-12 (USSR) 1958



MRBM R-14 at the launch position

the first time as components of rocket fuel, which ignited upon mutual contact. For the first time, membrane valves were also installed in the lines of each of the rocket fuel components, separating the rocket engine from the fuel tanks, which made it possible to keep the rocket fueled for a long time.

The rocket was equipped with an RD-216 main engine, which consisted of two identical engine blocks, united by a mounting frame with a body and having a common launch system, each of which had two combustion chambers, a fuel pump, a gas generator and an automation system. For the first time, the TNA worked on the main components of the fuel, which made it possible to abandon the use of hydrogen peroxide and simplify the operation of the rocket. The liquid-propellant rocket engine developed a thrust on the ground of 138 tons, had a dry weight of 1325 kg and a height of 3.49 m. Its operating time was about 170 seconds.

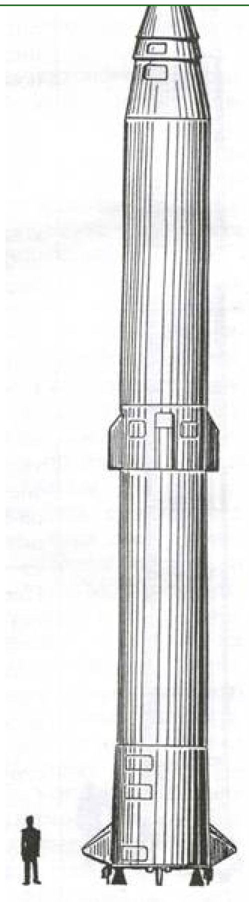
Installation of the R-14 MRBM at the launch position

The combustion chambers of the liquid-propellant rocket engine are of brazed-welded design with internal and regenerative cooling. The camera body is formed by two shells - a bronze fire wall and a steel jacket, which are connected through corrugated spacers. The TNA contained two centrifugal fuel screw pumps with double-sided inputs and an axial two-stage active turbine located on two shafts. The gas for the TPU drive was produced in a gas generator by burning a small part of the fuel with an excess of fuel. The exhaust gas was ejected by the turbopump unit through a special nozzle. The automation units were triggered by electrical and pyro commands, as well as by the control pressure of nitrogen, which was supplied to the gearbox from the on-board cylinders. The liquid-propellant rocket engine was regulated in terms of thrust by changing the fuel consumption through the gas generator, and in terms of the ratio of fuel components - by changing the consumption of the oxidizer. Thrust vector control was carried out using gas rudders.

The R-14 rocket had an autonomous inertial control system. For the first time, a gyro-stabilized platform with air suspension of gyroscopes, as well as a program pulse generator, was used. Gas-jet rudders were used as controls. The control system provided a range of about 1.9 km.

The rocket was equipped with a monoblock nuclear warhead with a power of 1 Mt, which was separated in flight. In order to prevent the rocket body from colliding with the warhead in the first seconds after separation, three powder braking rocket engines were used, which were turned on at the moment the sustainer rocket engine ended operation. The missile had systems for emergency detonation of the warhead and shutdown of the remote control in the event of a significant deviation of the missile from the specified flight path. The missile was launched from a ground launcher. The rocket was refueled and aimed after it was installed on the launch pad.

The designers managed to achieve a higher launch readiness of the rocket compared to previously adopted rocket models. The new missile system was more reliable in operation, but work to improve it continued. The desire to increase survivability led to the development of a silo-based version of the R-14 missile. The first launch of the modernized R-14U rocket took place on February 11, 1962. The tests were carried out at the Kapustin Yar test site, where a special silo launcher was built. In October of the following year, they were successfully completed and the new DBK was adopted by the Strategic Missile Forces and was used until the mid-80s. The last R-14U missile was eliminated in accordance with the provisions of the INF Treaty.



BRSD R-14 (USSR) 1961

The modified missile was more advanced than the R-14. It was equipped with a remote control system for refueling and compressed gases. Silo launchers had significant advantages over ground launches in terms of protection from the damaging factors of a nuclear explosion, and also ensured long-term maintenance of missiles in readiness for launch.

The R-14 rocket was used for space purposes. On its basis, the geophysical rocket "Vertical" was created, used to carry out the international program of cooperation of socialist countries in the field of research and use of outer space (Intercosmos). At the top of the rocket was a high-altitude probe with scientific equipment and service systems. The missiles were launched to altitudes of 500-1500 km. After the completion of the program, the probe with scientific equipment descended to Earth using a parachute system. The first launch of the Vertical rocket under the Intercosmos program took place on November 28, 1970.

In 1962, the world was on the brink of nuclear war. A crisis erupted as a result of the negative development of the military-political situation in the Caribbean after the Cuban revolution, which dealt a significant blow to the economic interests of North American companies. There was a real threat of American intervention in Cuba. Under these conditions, the USSR decided to provide assistance, including military assistance, to the government of Cuba. Considering that American Jupiter missiles from Turkey could reach the vital centers of the Soviet Union in just 10 minutes, and Soviet ICBMs needed at least 25 minutes to retaliate on American territory, Khrushchev ordered the deployment of Soviet IRBMs in Cuba with Soviet military personnel.

In accordance with the plan for Operation Anadyr, it was planned to deploy three regiments of R-12 missiles (24 launchers) and two regiments of R-14 missiles (16 launchers) on Cuban territory, which were ordered to be ready on a signal from Moscow to strike the most important facilities in the United States.

Under conditions of strict secrecy, the R-12 missiles were delivered to Cuba, where launch pads were built for them by Soviet military personnel. American intelligence was unable to detect them in a timely manner. Only a month after the arrival of three missile regiments on the island, the American U-2 aerial reconnaissance aircraft was able to photograph the launch pads and missiles, which caused great concern in the Pentagon, and then in President John Kennedy.

By the end of October, approximately half of the 36 R-12 missiles delivered to the island were ready to be filled with fuel, oxidizer, and docked with nuclear warheads. Due to the naval blockade of the coast of Cuba, the R-14 missiles did not arrive on the island. It was at this time that the leaders of the USSR and the USA came to the conclusion that the conflict must be resolved peacefully. During the negotiations, the parties agreed to remove Soviet MRBMs from Cuba, and American ones from Turkey and Europe. And yet, one P-12 remained on the island of freedom, but as a monument. Missiles of this type were the only ones of all the missiles ever in service with the Strategic Missile Forces that were destined to travel outside the Soviet Union.

Geophysical rocket "Vertical" (USSR)

The Cuban missile crisis had a significant impact on the development of strategic weapons, including MRBMs. For the Soviet Union and the United States, there was a significant break in the creation of new models of this class of missiles for other reasons. Thus, the USSR possessed two medium-range missile systems that were perfect for that time, which since 1964 were transferred to the silo-based method. And the United States, having lost the basing areas for medium-range missiles in Europe and Turkey, lost interest in IRBMs for more than 10 years, concentrating its main efforts on the development of submarine-launched ballistic missiles capable of replacing them.

In the first half of the 60s, China took up the development of its own missile forces. Mao Zedong put forward the concept of creating a great China, which was supposed to become the leader of the entire Asian world. To support such aspirations, a powerful rocket fist was needed. Even during the period when good neighborly, including military, ties existed between the Soviet Union and China, the latter received some technical information on the R-12 missile. But after the breakdown of relations, all military assistance to China ceased. Chinese designers had no choice but to try, using the Soviet rocket as a basis, to create their own analogue. It took seven long years before the Chinese were able to bring their rocket into mass production. It should be noted that China has surpassed even the Soviet Union in classifying information about missile technology. This explains the paucity of information about Chinese rocket technology that appears in the public press.

The technical characteristics of the rocket, and the entire complex as a whole, turned out to be low. By the time it entered combat units in 1970, it was already obsolete. Low production technology, as well as an insufficient level of mechanical engineering, determined the low probability of delivering warheads to the target - 0.5.

The Dun-1 missile (China has a different classification for ballistic missiles, different from the European one) is single-stage, made according to the usual layout and is very similar in appearance to the Soviet R-12. It consisted of a head part, an adapter, oxidizer and fuel tanks, an instrument compartment located in the intertank space and a tail compartment.

MRBM S-2 (France) 1971

The propulsion system included a four-chamber liquid propellant engine with one common turbopump unit. Kerosene and inhibited nitric acid were used as fuel components.

An inertial control system was installed on the rocket, which ensured a hit accuracy of about 3 km with a maximum flight range of 2000 km. The executive bodies were gas-dynamic rudders.

The Chinese had significant difficulties creating a nuclear charge for the missile. Until 1973, Dun-1 was equipped with a warhead with a power of 20 kt, which was very modest for a ballistic strategic missile with such accuracy. And only then was it possible to increase the charge power to 700 kt.

The missile was stationary. The security of the complex was weak - only 0.3 kg/cm². To prevent the defeat of several group launches by one combat unit, from the mid-70s they began to create separate ground launches spaced a short distance apart. But this could not improve the overall picture. Even the Chinese military leaders, who were not spoiled by the high combat characteristics of the weapons, complained about the very significant shortcomings of this missile system.

During these same years, in another part of the world, France (the only Western European country) began developing its own ballistic missile for military purposes. After leaving the NATO military organization, the French leadership set a course for pursuing its own nuclear policy. Such independence also had negative aspects. We had to start development from scratch. A number of companies were attracted to create the first medium-range missile. Later, the leading companies "Aerospatial", "Nord Aviation", "Sud Aviation" joined forces. A French laboratory for ballistic and aerodynamic research was created.

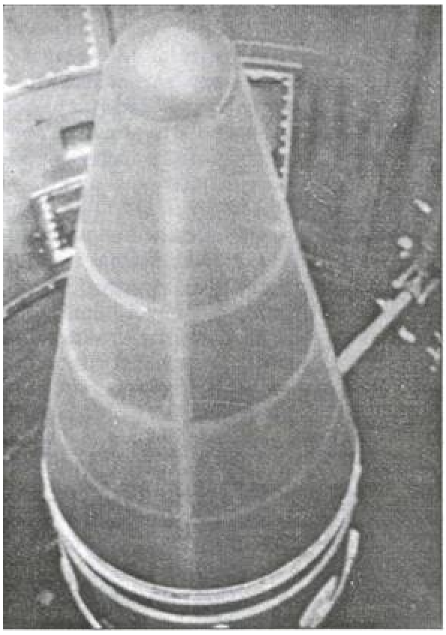
At the beginning of the 60s, the theoretical development program was completed. Flight tests of prototype missiles were carried out at a test site located in Algeria. In 1963, designers began creating a rocket that was supposed to go into service. According to the terms of the technical specifications, it had to be carried out with solid fuel engines. Basing and launching - from the mine.

In 1966, the S-112 two-stage ballistic missile was transferred for flight testing. It became the first French rocket to be launched from a silo. It was followed by the experimental S-01 and, finally, in May 1969, testing began on the first prototype medium-range ballistic missile, designated S-02. They lasted two years and ended in complete success. In the summer of 1971, serial production of the S-2 MRBM began and the formation of two missile groups for the operation of the missile system among the troops. The groups were deployed on the Albion plateau in the province of Provence.

The two-stage S-2 rocket was made according to the "tandem" design with a sequential arrangement of stages. The first of them was equipped with a solid fuel rocket engine, which had four rotary nozzles. It developed a ground thrust of 55 tons and could operate for 76 seconds. The stage body was made of steel.

The second stage was smaller and lighter than the first. A solid propellant rocket engine with four rotating nozzles was used as a propulsion engine, developing a thrust of 45 tons. Its operating time was 50 seconds. Mixed fuel, the same for both engines.

additional stability, aerodynamic stabilizers were attached to the rear skirt of the first stage. The rocket was equipped with a monoblock nuclear warhead with a power of 150 kt, detachable in flight.

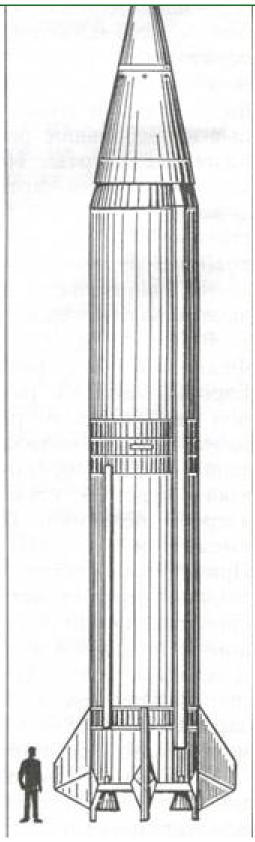


IRBM S-3 in silo

The missile system with the S-2 MRBM had a high degree of readiness for launch. The rocket was launched from a silo launcher due to the working remote control of the first stage. Pre-launch operations took place automatically after receiving a command from the missile group command post.

By the time all 18 missiles were fully deployed, the French military leadership came to the conclusion that the missile should be modernized, since it no longer met the requirements for an IRBM. Therefore, already in 1973, work began on its modernization and modifications to the entire DBK.

In December 1976, a new French medium-range missile, designated S-3, made its first flight. It was created in such a way as to replace its predecessor with minimal modifications to the silo. To fulfill this requirement, the first stage from the S-2 had to be left on the new rocket. But the second stage was thoroughly redesigned. The solid propellant engine now had only one rotating nozzle. An increase in the energy characteristics of the mixed fuel made it possible to reduce the length of the body and the mass of the stage while simultaneously increasing the maximum flight range to 3,700 km. The missile was equipped with an upgraded inertial control system, providing a hit accuracy of 700 m.



IRBM "Dong-2" (China) 1975

Combat equipment has also changed. Now the power of the head part was 1.2 Mt. In addition, the missile carried a set of means to overcome enemy missile defenses (before that, only one state in Europe had such a system - the Soviet Union). Technical readiness for the start was 30 seconds.

Some of the equipment of the command posts of the missile groups was also replaced. A new automated combat control system was installed, and the reliability of transmitting the launch order from the command post to the silo was increased. The latter have increased protection, especially from the neutron flux resulting from the explosion of a nuclear charge. The new DBK with the S-3 missile was put into service in 1980 and is in operation to this day.

But let's go back to the end of the 60s, to China. There, at this time, rocket designers began creating a new, more advanced medium-range missile. Limited range flight tests of the Dun-2 missile began in 1971. The entire testing program was completed only in 1975, after which this missile began to be delivered to military units.

The Dun-2 rocket is single-stage, with engines running on liquid fuel (fuel - unsymmetrical dimethylhydrazine, oxidizer - inhibited nitric acid). The propulsion system consists of two identical two-chamber engines, each of which has its own turbopump unit.

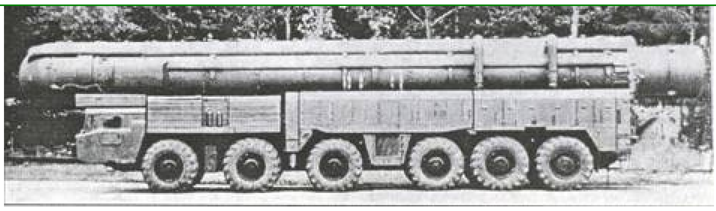
The inertial control system provided control of the missile's flight in the active part of the trajectory and a hit accuracy of 2.5 km when firing at a maximum range of 4000 km. The executive elements of the system were gas-dynamic rudders. Stabilizers were attached to the tail skirt to give the rocket additional stability when passing through dense layers of the atmosphere.

"Dun-2" carried the same head section as its predecessor. The developers of the complex managed to slightly improve the performance characteristics. The pre-launch preparation time decreased and amounted to 2–2.5 hours. If the rocket was pre-filled with fuel components, then this time was reduced to 15–30 minutes. "Dun-2" could be launched from a ground or from a silo launcher, where it was installed before the launch. Typically, missiles were stored in underground secure storage.

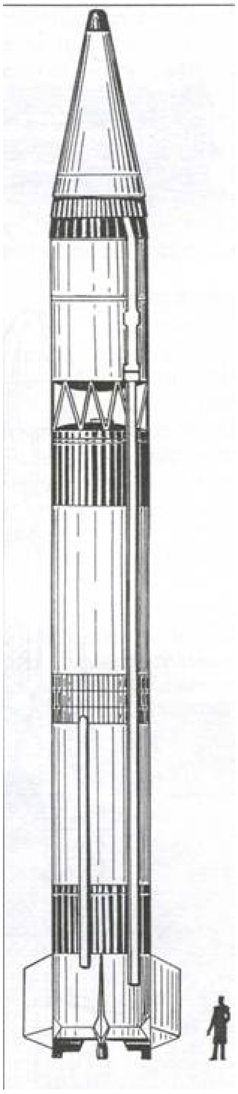
Two years later, the new Dong-2-1 MRBM (according to the Chinese classification, an intermediate-range missile) was put on combat duty. It was two-stage. The first stage was taken from Dun-2 without any changes. The second stage, docked using a connecting compartment of a truss structure with the first, had a single-chamber liquid propellant engine with a rotating nozzle as a propulsion system.

The Chinese failed to improve the inertial control system. When firing at a maximum range of 6000 km, the probable miss increased to 3.5 km. True, the power of the nuclear warhead increased to 2 Mt, which somewhat compensated for the rather large deviation from the calculated aiming point. But the missile was still not capable of hitting highly protected point targets, which limited the choice of targets. The operational performance of Dun-2-1 remained at the level of its predecessor. The technical reliability of the missiles also remained low.

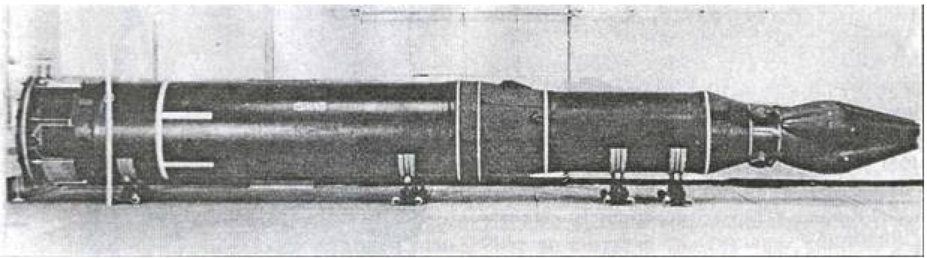
Of course, it is difficult to call all Chinese MRBMs of this period perfect, but it was still necessary to take them into account. The Soviet Union's relations with China took on a conflictual form by the end of the 60s, and after armed Chinese provocations on the Far Eastern border of the USSR they completely deteriorated. Under these conditions, the appearance of a nuclear-armed MRBM in an aggressive neighbor required retaliatory steps.



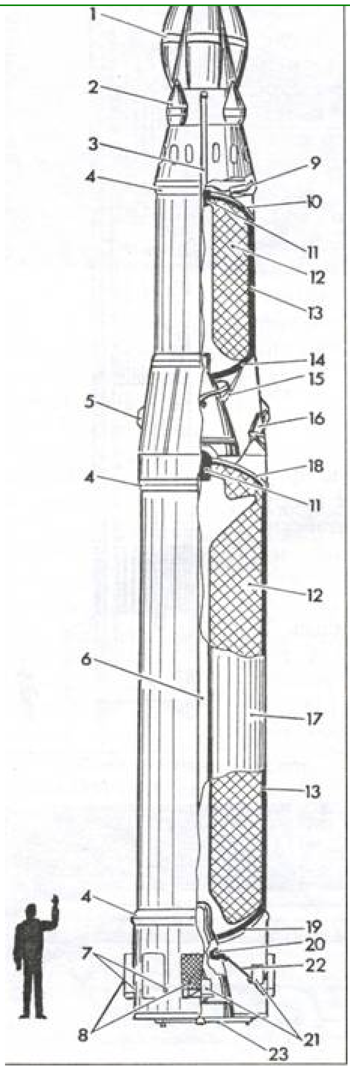
SPU DBK "Pioneer"



IRBM "Dong-2-1" (China) 1977



IRBM "Pioneer"



IRBM "Pioneer" (USSR) 1976

1 — warhead fairing; 2 — combat stage engine fairing; 3 - cable box; 4 — support belt; 5 — brake motor fairing; 6 - cable box; 7 — places where the aerodynamic rudder is attached; 8 — aerodynamic rudders; 9 — second stage brake motor; 10 — top cover of the solid propellant rocket motor; 12 — fuel charge; 13 — thermal protection; 14 — bottom cover of the solid propellant rocket engine; 15 — gas injection device into the nozzle; 16 — first stage brake motor; 17 — rocket body; 18 — upper cover of the first stage solid propellant rocket engine; 19 — rear cover of the first stage solid propellant rocket engine; 20 — gas-dynamic steering wheel; 21 — steering gears; 22 — mechanical connection between the aerodynamic and gas-dynamic rudders; 23 — protective nozzle cover.

The question arose - what to do? Build new positions for missiles like R-12 and R-14, or come up with something new. This is where the developments of the Moscow Design Bureau under the leadership of Academician A.D. Nadiradze came in handy. It was developing a medium-range missile using mixed solid fuel. The great advantage of a new missile system with such a missile should have been the use of a mobile basing method, which promised increased survivability due to the uncertainty about the location of the launcher. If necessary, the prospect of relocating mobile launchers from one theater of operations to another opened up, which is impossible with stationary basing of missiles.

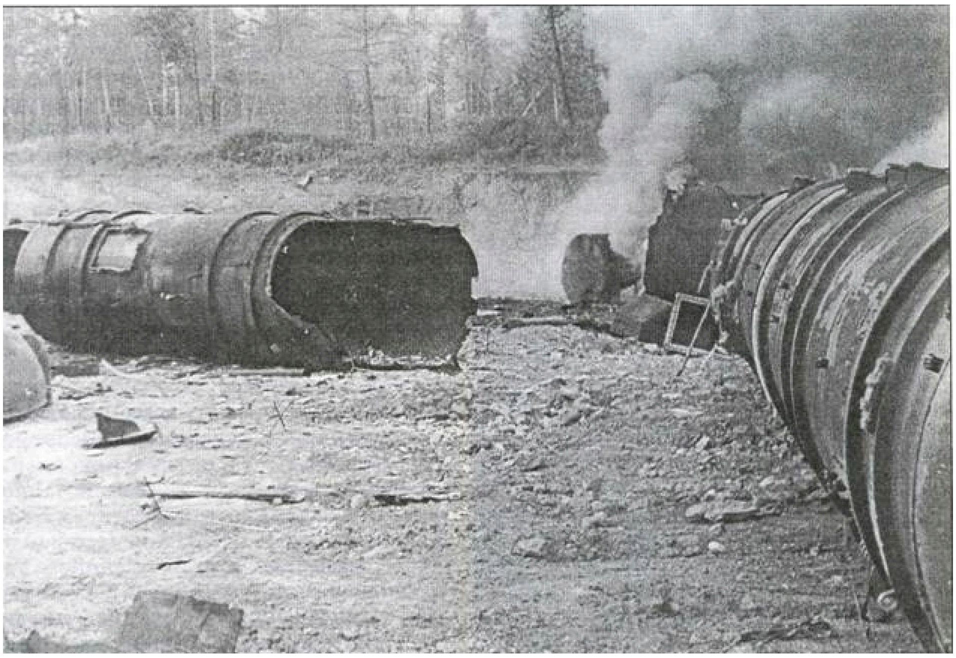
In the early 70s, the work was given additional acceleration. After practical testing of various technical solutions for the new rocket and ground-based units of the missile system, the designers were able to begin the final stage. On September 21, 1974, flight tests of the Pioneer rocket (factory designation 15Zh45) began at the Kapustin Yar test site. It took almost a year and a half to complete the development of the rocket and complete the planned test program. On March 11, 1976, the State Commission signed an act on the acceptance of the DBK with the 15Zh45 missile (another designation RSD-10) into service with the Strategic Missile Forces. The complex was also given the name “Pioneer”. But this DBK was not the first mobile complex. Back in the mid-60s, a mobile missile system was tested in the USSR, in which a rocket with a liquid-propellant rocket engine was installed on a tracked chassis. But due to the large mass of the structure and other shortcomings, they did not bring it to mass production.

New complexes were deployed not only in the east, but also in the west of the Soviet Union. Some of the obsolete medium-range missiles, primarily the R-14, were removed from service, and their place was taken by the Pioneers. The appearance of the latter caused a great stir in NATO countries, and very quickly the new Soviet missile became known as the SS-20 - “The Thunderstorm of Europe”.

The Pioneer rocket had two sustainer stages and an instrumentation unit, which were connected to each other using connecting compartments. The first stage propulsion system was a structure consisting of a fiberglass body with a solid propellant charge attached to it, made of high-energy mixed fuel, a steel front bottom and nozzle cover, and a nozzle block. The tail section of the stage housed brake motors

The second stage propulsion system had a similar design, but other methods were used to obtain control inputs. Thus, control of pitch and yaw angles was carried out by blowing gas from a gas generator into the supercritical part of the nozzle, and control of roll was carried out by bypassing gas through a special device. Both engines had a thrust cut-off system (at the first stage - emergency) and an operating time of about 63 seconds.

An inertial control system based on an on-board digital computer complex was installed on the rocket. To increase operational reliability, all channels had redundancy. Almost all elements of the control system were located in a sealed instrument compartment. The designers managed to ensure a fairly high hit accuracy (HPA) - 550 m when firing at a maximum range of 5000 km.



Elimination of Pioneer MRBMs and their containers

The instrumentation unit ensured the deployment of three warheads with a yield of 150 kt each for their own purposes. Flight tests of the rocket were also carried out with a monoblock warhead with a power of 1 Mt. Due to the lack of probable targets of the missile defense system in the areas of choice, the missile did not have a complex to overcome it.

The MAZ-547 six-axle wheeled vehicle was chosen as the chassis for the mobile launcher. The rocket, placed in a sealed transport and launch container, in which the required temperature and humidity conditions were constantly maintained, was in a horizontal position before launch. In preparation for launch, the TPK was raised to a vertical position. In order not to destroy the launcher, the designers used the “mortar” launch method. Pre-launch preparation and launch operations took place automatically after receiving a special command from the control point.

On August 10, 1979, the 15Zh53 rocket, which had higher combat characteristics, was presented for flight testing. Tests were carried out at the Kapustin Yar training ground until August 14, 1980, and on December 17 of the same year, the new DBK, designated “Pioneer UTTH” (improved tactical and technical characteristics), was adopted by the Strategic Missile Forces.

The Pioneer UTTH rocket had the same first and second stages as the Pioneer rocket. The changes affected the control system and the instrumentation unit. By improving the command instruments and operating algorithms of the on-board control system, it was possible to increase the firing accuracy to 450 m. The installation of new engines with increased energy on the instrumentation unit made it possible to increase the deployment area of warheads, which was of great importance when planning destruction targets.

Both complexes were in operation until 1991 and were liquidated in accordance with the terms of the INF Treaty. Some of the missiles were eliminated by launch, which made it possible to check their reliability and confirm the intended characteristics. Of particular interest were the Pioneer rockets, which had been in operation for over 10 years. The launches were completed successfully. In total, over 700 deployed and stored RSD-10 missiles were cut.

IRBM "Pioneer" at the moment of launch

In the early 70s, the United States returned to the creation of MRBMs, which was a consequence of a change in the military-political balance with the USSR. The real possibility of receiving a powerful retaliatory strike on their territory forced American strategists and politicians to look for an acceptable way out. When they look hard enough, they almost always find it. American strategists developed the concept of "limited nuclear war." Its main highlight was the idea of transferring the nuclear conflict to the vastness of Europe, naturally, with the seizure of the territory of the Soviet Union. To implement new ideas, new means were needed. In 1972, theoretical studies began on this problem, which made it possible to develop a set of tactical and technical requirements for the future missile system. Since the mid-70s, a number of rocket manufacturing companies have been carrying out development work to create a prototype MRBM capable of satisfying the customer.

The victory was won by Martin-Marietta (the parent company), with which the contract for the full-scale development of a combat missile system was signed in 1979. At the same time, politicians began actively working with their European allies in the North Atlantic bloc in order to achieve permission to deploy new American missiles. As always, a proven trump card was used - the "Soviet missile danger", and above all, from the SS-20 missiles. Consent to the basing of the MRBM was obtained from the German government.

In the meantime, design work was completed, and in April 1982 the rocket, which by that time had received the name "Pershing-2", entered flight tests. It was planned to carry out 14 control launches and 14 so-called military launches, i.e., by regular crews.

The first two launches, on June 22 and November 19, ended unsuccessfully. The designers quickly figured out the reasons and the subsequent 7 test launches in January-April next year at a distance of 100 to 1650 km were considered successful. A total of 18 test launches were carried out, after which it was decided to accept the complex with the Pershing 2 missile into service with the 56th brigade of US ground forces in Europe, the rearmament of which began at the end of 1983.

To be fair, it should be noted that American strategists never planned to use the 120 Pershing-2 MRBMs stationed on the territory of West Germany against Soviet SS-20 missiles. This conclusion is easy to draw by comparing at least the number of both missiles: 120 for the Americans and over 400 for the Soviet Union in the territory up to the Urals. The purpose of the Pershings was completely different. Possessing high hit accuracy and short approach time to targets, which neither ICBMs nor SLBMs could provide, they were "first strike" weapons. Their main purpose is to defeat strategically important targets and, above all, command posts of the Armed Forces and Strategic Missile Forces of the USSR, in order to weaken the retaliatory nuclear strike as much as possible, if not completely disrupt it.

According to its layout scheme, the Pershing-2 MRBM was a two-stage rocket with a sequential arrangement of stages connected to the warhead through transition compartments. A characteristic feature of the missile is the placement of its control system in the head section, as well as the presence of a thrust cut-off system on both solid fuel stages, which has not previously been seen on American missiles.

The design of the solid propellant rocket engines of the sustainer stages was the same and consisted of the following main elements: a body made of a composite material based on Kevlar-49 fiber with a thermal insulation coating, a nozzle block rigidly attached to the body of the solid propellant charge, an igniter, a thrust vector control drive and a thrust cut-off system. The designers used nozzles with an increased degree of expansion, which were deflected using an electrically controlled hydraulic drive. The engine operating time until the fuel is completely burnt out is 55 and 40 seconds for the first and second stages, respectively. The use of a thrust cut-off system made it possible to obtain a wide range of flight ranges.

The warhead consisted of three compartments: the front (it housed the explosion sensors and elements of the guidance system), the middle (warhead) and the rear (the inertial control system and its actuators).

The rocket flight control in the active part of the trajectory in pitch and yaw angles was carried out by deflecting the solid propellant rocket motor nozzles. Roll control during the operation of the first stage engine was carried out by two aerodynamic rudders installed on the tail section

The control system was supplemented by a guidance system for the warhead at the final part of the trajectory using a radar map of the area (RADAG system). Such a system has not previously been used on ballistic missiles. The Kearfott command instrument complex was located on a stabilized platform placed in a cylindrical housing and had its own electronic control unit. The operation of the control system was ensured by an on-board digital computer complex from Bendix, housed in 12 removable modules and protected by an aluminum case.

The RADAG system consisted of an airborne radar station and a correlator. The radar was shielded and had two antenna units. One of them was intended to obtain a radar brightness image of the area. The other is for determining flight altitude. The ring-type image under the head was obtained by scanning around the vertical axis at an angular velocity of 2 rps. Four reference images of the target area for different altitudes were stored in the digital computer memory in the form of a matrix, each cell of which represented the radar brightness of the corresponding terrain area, written in a two-digit binary number. The actual image of the terrain received from the radar was reduced to a similar matrix; by comparing it with the reference image, the error of the inertial system could be determined.

The flight of the warhead was corrected by executive elements - jet nozzles powered by a compressed gas cylinder outside the atmosphere, and hydraulically driven aerodynamic rudders upon entry into the atmosphere.

As combat equipment, the missile carried a nuclear monoblock with a variable TNT equivalent. Before the launch, the launch control crew could choose one of four possible powers: 0.3, 2, 10, 80 kt. To destroy highly protected objects, a nuclear charge penetrating 50–70 m deep into the earth was developed.

The Pershing 2 missile was placed on a launcher mounted on a wheeled semi-trailer and raised to a vertical position before launch. Unlike the Soviet RSD-10, it did not have a transport and launch container. To protect the rocket from precipitation, dust and dirt during the march, special covers were used.

All 108 Pershing 2 missiles put on combat duty were based in West Germany until 1990, until they were eliminated in accordance with the provisions of the INF Treaty. Despite the fact that this missile was designed in the second half of the 70s, it still remains the most advanced MRBM in the world.

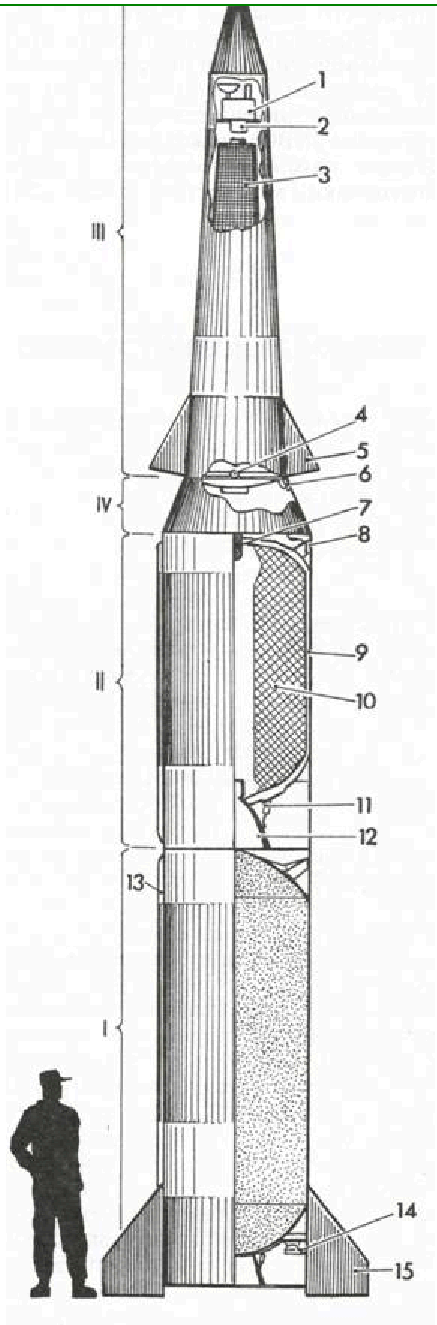
In the 1980s, France and China were developing medium-range ballistic missiles. And if the first country does not show much activity, the Asian giant spends a lot of money on it. Chinese rocket specialists, taking advantage of positive changes in the country's economy, created the Dong-4 missile with a flight range of up to 6000 km in the second half of the 80s. Its launch mass reaches 90 tons. Significant progress has been achieved in the field of guidance systems. The new inertial control system ensures delivery of a 2Mt warhead to the target with an accuracy of 700 m. The silo placement of missiles filled with liquid fuel components ensures pre-launch preparation and launch within 3–5 minutes. Since 1988, Dun-4 missiles have been supplied to replace outdated systems.

The Chinese are also developing rockets with solid fuel engines. It will have two sustainer stages, a monoblock warhead with a power of 350 kt, a maximum flight range of about 3000 km, and a shooting accuracy of 500 m. In order to increase the survivability of the missile, a mobile launching method has been chosen. It is expected that it will enter service with the PLA nuclear forces in the late 90s. If successful, this missile could become the most advanced of all Chinese ballistic missiles and bring China's strategic nuclear forces to a new qualitative level.

In France, work is underway on the S-4 rocket, the completion of which is planned for the beginning of the next millennium. It is expected that it will be suitable for deployment both in silos and on self-propelled launchers, have a flight range of about 3500 km and a CEP of 300 m.

India is creating its own IRBM. Flight tests of the Agni missile have been carried out at the Chandipur missile test site since May 1989. According to press reports, work is progressing well. The rocket is two-stage. The first stage (solid propellant rocket engine) is taken from an Indian launch vehicle used to launch satellites into space. The second stage is a nationally developed Prithvi operational-tactical missile. It is equipped with a two-chamber liquid propellant engine with deflectable combustion chambers.

The rocket's control system is inertial, built on the basis of an on-board computer. A number of variants of warheads are being developed for the Agni: with a conventional explosive weighing 1000 kg, a volumetric explosion, as well as a warhead with a correction system at the end of the flight based on a radar or infrared map of the area in the target area. If the work is successfully completed, the firing accuracy (CAO) may be 30 m. It is quite possible to create a nuclear warhead with a yield of about 20 kt.



IRBM "Pershing-2" (USA) 1985

I - first stage; II - second stage; III - head part; IV - transition compartment; 1 — onboard radar of the RADAG system; 2 — sensor for special automatics of a nuclear charge; 3 — combat unit; 4 — jet nozzle of the warhead flight control system; 7 — solid propellant rocket launcher; 8 — solid propellant rocket motor thrust cut-off device; 9 — engine thermal protection; 10 — charge of solid fuel; 11 — nozzle deflection mechanism; 12 — solid propellant nozzle; 13 - cable box; 14 — steering gear; 15 — aerodynamic rudder of the first stage

The Indian MRBM has a launch weight of 14 tons, a length of 19 m, a diameter of about 1 m and a flight range of 2500 km. Its adoption is expected in the late 90s.

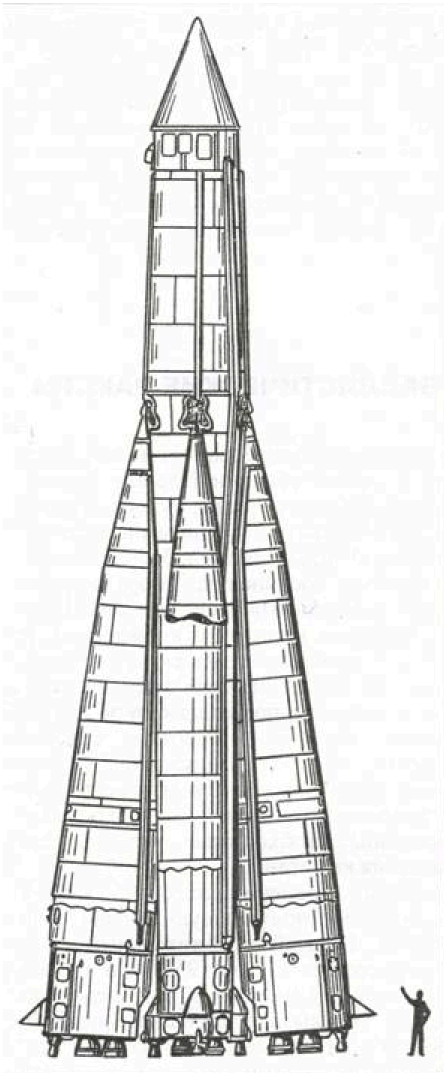
Thus, at the beginning of the new century, China, France and India will have MRBMs in service, although it is possible that missiles of this type may also appear in other countries.

Chapter 3. Intercontinental ballistic missiles

By the mid-50s, almost simultaneously, the military leaders of the Soviet Union and the United States set their missile designers the task of creating a ballistic missile capable of hitting targets located on another continent. The problem was not simple. A lot of complex technical issues related to ensuring the delivery of a nuclear charge to a range of over 9,000 km had to be resolved. And they had to be solved by trial and error.

N. S. Khrushchev, who came to power in the USSR, realizing the vulnerability of strategic aviation aircraft, decided to find a worthy replacement for them. He bet on rockets. On May 20, 1954, a joint decree of the government and the CPSU Central Committee was issued on the creation of an intercontinental-range ballistic missile. The work was entrusted to TsKB-1. Its head, S.P. Korolev, received broad powers to marked the beginning of the creation of a new test site (now known as the Baikonur Cosmodrome) for testing the tactical and technical characteristics of ICBMs, launching artificial satellites, and performing research and experimental work on rocket and space technology. A little later, in the area of the Plesetsk station in the Arkhangelsk region, the construction of a facility under the code name "Angara" began, which was to become the base of the first formation armed with new missiles (later it began to be used as a training ground and cosmodrome). In difficult conditions, it was necessary to build launch complexes, technical positions, measuring points, access roads, living and working premises. The brunt of the work fell on the military personnel of the construction battalions. Construction was carried out at an accelerated pace and within two years the necessary conditions for testing were created.

By this time, the TsKB-1 team had created a rocket, designated R-7 (8K71). The first test launch was scheduled for May 15, 1957 at 19.00 Moscow time. As one might expect, it aroused great interest. All the chief designers of the rocket and launch complex, program managers from the Ministry of Defense and a number of other organizations arrived. Everyone, of course, hoped for success. However, almost immediately after the command to start the propulsion system passed, a fire broke out in the tail compartment of one of the side blocks. The rocket exploded. The next launch of the S7, scheduled for June 11, did not take place due to a malfunction of the central unit remote control. It took the designers a month of persistent and painstaking work to eliminate the causes of the identified problems. And on July 12, the rocket finally took off. Everything seemed to be going well, but only a few tens of seconds of flight passed, and the rocket began to deviate from the intended trajectory. A little later it had to be liquidated. As we later found out, the cause was a violation of the missile's flight control along the rotation channels.



ICBM R-7A (USSR) 1960

The first launches showed the presence of serious flaws in the design of the R-7.

When analyzing telemetry data, it was found that at a certain moment, when the fuel tanks were emptied, pressure fluctuations occurred in the supply lines, which led to increased dynamic loads and structural destruction. To the credit of the designers, they quickly dealt with this defect.

The long-awaited success came on August 21, 1957, when the launched rocket completely completed its planned flight plan. And on August 27, a TASS message appeared in Soviet newspapers: "Recently, a new ultra-long-range multistage ballistic missile was launched. The tests were successful. They fully confirmed the correctness of the calculations and the chosen design... The results obtained show that it is possible to launch missiles to any region of the globe." This statement, naturally, did not go unnoticed abroad and had the desired effect.

This success opened up broad prospects not only in the military field. At the end of May 1954, S.P. Korolev sent a letter to the Central Committee of the CPSU and the Council of Ministers of the USSR with a proposal to carry out the practical development of an artificial Earth satellite. N.S. Khrushchev approved this idea and in February 1956, practical work began on preparing the first satellite and ground-based measurement and control complex. On October 4, 1957, at 22.28 Moscow time, the R-7 rocket with the first artificial satellite on board took off and successfully placed it into orbit. On November 3, the world's first biological satellite was launched, in the cabin of which there was an

Meanwhile, combat missile testers faced new difficulties. Since the warhead rose to a height of several hundred kilometers, by the time it returned to the dense layers of the atmosphere it accelerated to enormous speeds. The round-shaped combat unit, developed earlier, quickly burned out. In addition, it became clear that it was necessary to increase the maximum flight range of the rocket and improve its operational characteristics.

On July 12, 1958, the task for the development of a more advanced rocket, the R-7A, was approved. At the same time, the "seven" was being fine-tuned. In January 1960, it was adopted by the newly created branch of the Armed Forces - the Strategic Missile Forces.

The two-stage R-7 rocket is made according to a "package" design. Its first stage consisted of four side blocks, each with a length of 19 m and a maximum diameter of 3 m, located symmetrically around the central block (the second stage of the rocket) and connected to it by the upper and lower belts of power connections. The design of all blocks is the same: the tail compartment, the power ring, the torus tank compartment for storing hydrogen peroxide used as the working fluid of the pump, the fuel tank, the oxidizer tank and the front compartment.

At the first stage, in each block, an RD-107 liquid-propellant rocket engine designed by GDL-OKB with pump supply of fuel components was installed. It had six combustion chambers. Two of them were used as helmsmen. The liquid-propellant rocket engine developed a thrust at the ground of 78 tons and ensured operation at nominal mode for 140 seconds.

The second stage was equipped with an RD-108 liquid propellant rocket engine, similar in design to the RD-107, but differing mainly in the large number of steering chambers - 4. It developed thrust at the ground up to 71 tons and could operate in the main stage mode for 320 seconds.

The fuel for all engines was two-component: oxidizer - liquid oxygen, fuel - kerosene. The fuel was ignited during launch by pyrotechnic devices. To achieve the specified flight range, the designers installed an automatic control system for engine operating modes and a system for simultaneous tank emptying (SOB), which made it possible to reduce the guaranteed fuel supply. Previously, such systems have not been used on rockets.

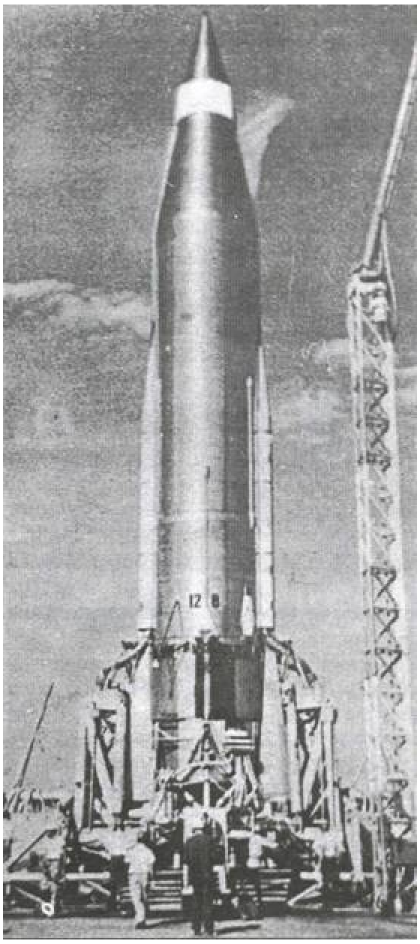
"Seven" was equipped with a combined control system. Its autonomous subsystem provided angular stabilization and stabilization of the center of mass in the active part of the trajectory. The radio subsystem corrected the lateral movement of the center of mass and issued a command to turn off the engines, which increased the accuracy of the rocket. The COE was 2.5 km when firing at a range of 8500 km.

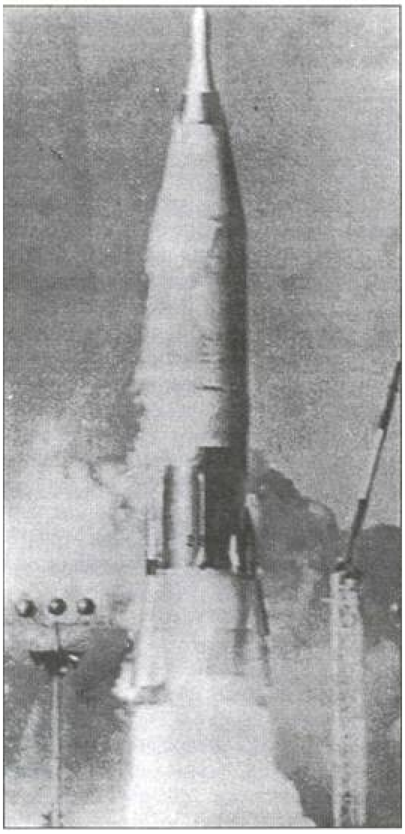
The R-7 carried a monoblock nuclear warhead with a capacity of 5 Mt. Before launch, the rocket was installed on the launch device. Containers with kerosene and oxygen were adjusted and the refueling process began, which lasted almost 2 hours. After the launch command passed, the engines of the first and second stages were simultaneously started. Noise-proof radio control commands were transmitted aboard the rocket from special radio control points.

The missile system turned out to be bulky, vulnerable and very expensive to operate. In addition, the rocket could remain in a fueled state for no more than 30 days. An entire plant was needed to create and replenish the necessary supply of liquid oxygen for deployed missiles. Very soon it became clear that the R-7 and its modifications could not be put on combat duty in large numbers. That's how it all happened. By the time the Cuban Missile Crisis arose, the Soviet Union had only a few dozen such missiles.

On September 12, 1960, a modified R-7A (8K74) missile was put into service. It had a slightly larger second stage, which made it possible to increase the flight range by 500 km, a lighter warhead and an inertial control system. But, as one would expect, it was not possible to achieve a noticeable improvement in combat and operational characteristics.

By the mid-60s, both missile systems were removed from service and the former R-7A ICBM began to be widely used for launching spacecraft as a launch vehicle. Thus, spacecraft of the Vostok and Voskhod series were launched into orbit by a three-stage modified modification of the "seven", consisting of six blocks: a central one, four side ones and a third stage block. Later it became the launch vehicle for the Soyuz spacecraft. Over the many years of space service, various rocket systems have been improved, but no fundamental changes have occurred.





Atlas-E ICBM (USA) 1962

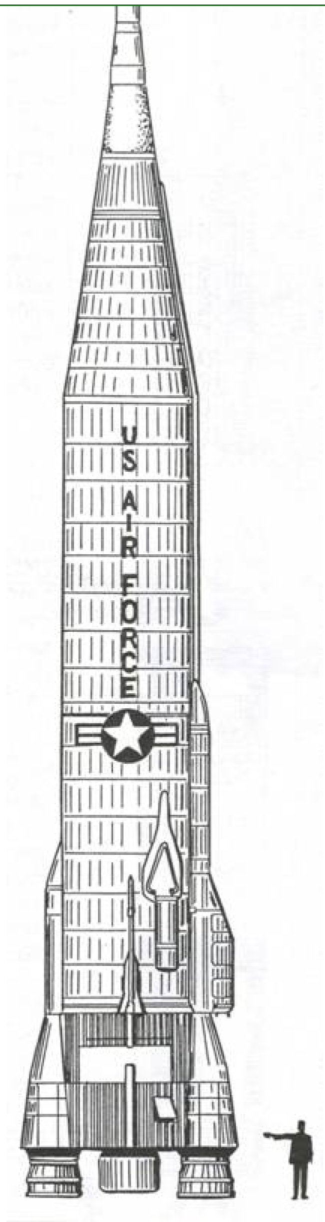
In 1953, the command of the US Air Force, after conducting another exercise on nuclear bombing of objects located on the territory of the USSR and calculating the probable losses of its aircraft, finally came to the conclusion that it was necessary to create ICBMs. The tactical and technical requirements for such a missile were formulated quickly and early next year the Convair company received an order for its development.

In 1957, representatives of the company submitted for testing a simplified version of the ICBM, which received the designation HGM-16 and the name “Atlas-A”. Eight missiles were built without a warhead and a second stage engine (it has not yet been brought to full readiness). As the first launches showed, which ended in explosions and failures, the first stage systems were far from the required conditions. And then the news from the Soviet Union about the successful test of an intercontinental missile added fuel to the fire. As a result, General Schriever, who was at that time the head of the US Air Force Ballistic Missile Directorate, almost lost his job and was forced to give official explanations about the failures in many state commissions.

A year later, the Atlas-V rocket, fully equipped, was handed over for testing. Throughout the year, launches were carried out at various ranges. The developers have made significant progress. On November 28, 1958, during the next launch, the rocket flew 9650 km and it became clear to everyone that the Atlas ICBM had taken place. This modification was intended to test the warhead and combat use techniques. All missile launches in this series were completed successfully (the first was on December 23, 1958). Based on the results of the latest tests, a batch of missiles, designated Atlas-D, was ordered for transfer to the SAC Air Force units. The first test launch of ICBMs from this series, which took place on April 14, 1959, ended in an accident. But it was an accident, which was later confirmed.

Work on the rocket did not end there. Two more modifications were created and put into service in 1962 - E and F. There is no reason to call them fundamentally new. Changes affected the control system equipment (the radio control system was eliminated), and the design of the nose of the rocket body changed.

The Atlas-F modification was considered the most advanced. It had a mixed design. At launch, all engines began to fire simultaneously, thus representing a single-stage rocket. After reaching a certain speed, the tail section of the hull was separated together with the so-called accelerator engines. The body was assembled from sheet steel. Inside there was a single fuel tank 18.2 m long and 3 m in diameter. Its internal cavity was divided by a partition into two parts: for oxidizer and fuel. To dampen fuel fluctuations, the internal walls of the tank had a “waffle” design. For the same purpose, after the first accidents, it was necessary to install a partition system. The tail part of the hull (skirt), made of fiberglass, which was dropped in flight, was attached to the lower bottom of the tank on the frame using explosive bolts.



Atlas-F ICBM (USA) 1962

The propulsion system, consisting of an LR-105 main engine, two LR-89 launch boosters and two LR-101 steering engines, was located at the bottom of the rocket. All engines were developed in 1954–1958 by Rocketdyne.

The sustainer rocket engine had an operating time of up to 300 seconds and could develop a thrust on the ground of 27.2 tons. The LR-89 rocket engine developed a thrust of 75 tons, but could operate for only 145 seconds. To provide pitch and roll flight control, its combustion chamber had the ability to deviate by an angle of 5 degrees. Many elements of this engine were identical to the rocket engine of the Thor rocket. In order to simplify the design for the two accelerators, the developers provided common elements of the launch system and a gas generator. Exhaust gases from the fuel pump were used to heat helium gas supplied to the fuel tank pressurization. The steering rocket engines had a thrust of 450 kg, an operating time of 360 seconds and could deviate at an angle of 70 degrees.

Kerosene and supercooled liquid oxygen were used as fuel components. Fuel was also used to cool the combustion chambers of liquid-propellant rocket engines. Powder pressure accumulators were used to launch all three TNAs. The consumption of components was regulated by a discrete fuel supply control system, special sensors and a computer. After the accelerators completed the given program, they were dropped along with the helium cylinders and skirt.

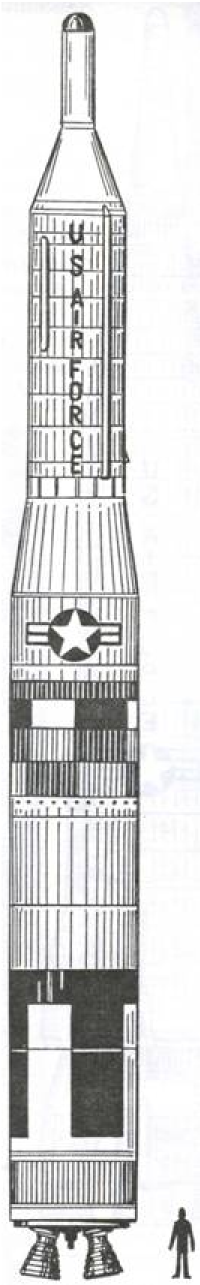
The rocket was equipped with an inertial-type control system from Bosch Arma with a discrete-type computer and electronic control device. The memory elements were made on ferrite cores. The flight program, recorded on magnetic tape or magnetic drum, was stored in the rocket silo. If there was a need to replace the program, a new tape or drum was delivered from the missile base by helicopter. The control system ensured the COE of the impact points of the warhead within a radius of 3.2 km when firing at a range of about 16,000 km.

The head part of the MKZ has a sharp conical shape (in series up to and including D, the MS had a blunter shape) of a detachable type in flight and was stabilized by rotation. Its mass was 1.5 tons. The nuclear monoblock with a capacity of 3–4 Mt had several degrees of protection and reliable detonation sensors. In 1961, the Mk4 warhead weighing 2.8 tons with a more powerful charge was developed, but they decided to install it on the Titan-1 ICBM.

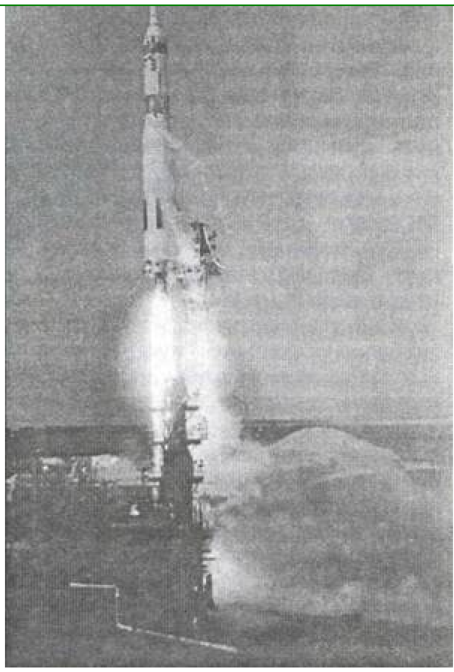
Atlas missiles were based in silos with lifting launch pads and were ready to launch in about 15 minutes. In total, the Americans deployed 129 launchers with these missiles and they were in service until the end of 1964.

Even before they were removed from combat duty, Atlases began to be used for space purposes. The Atlas-D rocket launched the Mercury spacecraft into orbit on February 20, 1962, with an astronaut on board. It also served as the first stage of the Atlas-Able three-stage launch vehicle. However, all three launches of this rocket in 1959–1960 from Cape Canaveral ended in failure. Atlas-F was used to launch satellites for

But let's go back. In 1955, the US Air Force Strategic Forces Command developed a set of requirements for a heavier missile capable of carrying a powerful thermonuclear warhead. The development task was received by the Martin company. Despite enormous efforts, development work on the LGM-25A missile has clearly been delayed. Only in the summer of 1959 an experimental series of missiles entered flight tests. The first launch, on August 14, was unsuccessful due to a malfunction that occurred in the second stage. Subsequent tests were accompanied by numerous failures and accidents. The finishing was difficult. Only on February 2 of the following year did the long-awaited success come. The test rocket finally took off. It would seem that the black streak is over. But on June 15, during preparations for the launch, an explosion occurred. On July 1, the rocket had to be blown up in flight due to a large deviation from the intended trajectory. And yet, the expended efforts of a large team of designers and the financial stimulation of the project yielded positive results, which were confirmed by subsequent launches.



Titan-1 ICBM (USA) 1961



Launch of the Titan-1 ICBM

On September 29, the Titan-1 rocket (this name was assigned to the new ICBM by that time) was launched at maximum range with an equivalent warhead of 550 kg, located in a special experimental building. The rocket launched from the Canaveral test site flew 16,000 km and fell into the ocean 1,600 km southeast of the island. Madagascar. A container with instruments that separated from the warhead at an altitude of 3 km was discovered and caught by the search team. In total, during the entire flight test cycle, which lasted until October 6, 1961, 41 experimental launches of Titan-1 missiles were carried out, of which 31 were considered successful or partially successful.

The two-stage Titan-1 ICBM is designed according to the "tandem" design. Each stage had two supporting fuel tanks made of high-strength aluminum alloy. The power set and the casing of the tail and instrument compartments were made of magnesium-thorium alloy. Despite its considerable size, the dry weight of the rocket did not exceed 9 tons. To slow down the first stage at the moment of separation, the remainder of the oxidizer from the tank was released through two jet nozzles located on the upper ring of the tank. At the same time, the second stage propulsion engine was turned on.

At the moment of launch on the ground, the two-chamber liquid-propellant rocket engine LR-87, designed by Aerojet General Corporation, was turned on, developing a thrust of 136 tons. The fuel supply allowed it to operate for 145 seconds. The launch of the TNA, which operated on the main fuel components, was carried out with compressed nitrogen. Cooling of the tubular combustion chambers was provided by fuel. The combustion chambers were installed in hinged suspensions, which made it possible to create control forces in flight at pitch and yaw angles.

Roll control was implemented through the installation of nozzle nozzles into which exhaust gases emanating from the TNA were supplied.

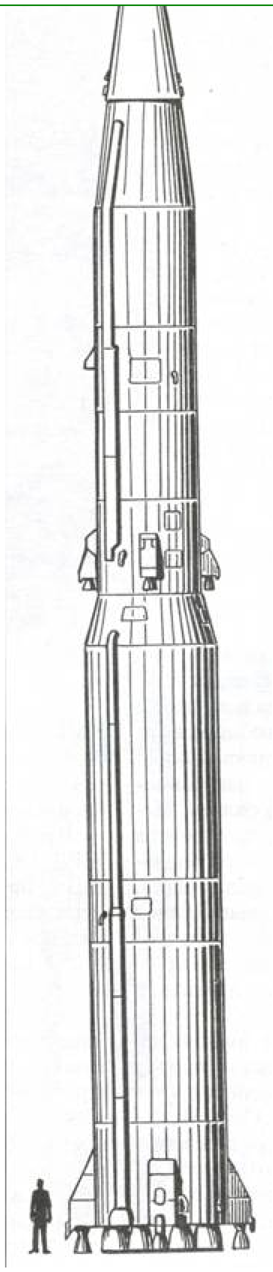
The second stage is equipped with a single-chamber liquid propellant rocket engine LR-91, which developed a thrust in vacuum of 36.3 tons. Its operating time is 180 seconds. The combustion chamber was mounted on a gimbal and had a tubular design. Part of the nozzle was cooled. The rest of it was a two-layer nozzle with an inner layer of phenolic plastic reinforced with asbestos. The exhaust gases after the turbine of the turbopump unit were ejected through a nozzle, which ensured the creation of forces along the roll angle. The fuel for all liquid rocket engines is two-component: fuel is kerosene, oxidizer is liquid oxygen.

The rocket was equipped with an inertial control system with radio correction on the active part of the trajectory using a ground-based computer. It included a tracking radar, a special computer "Athena" for calculating the actual trajectory, determining the moment to turn off the second stage propulsion system and generating control commands. The inertial device on board the rocket functioned for only two minutes and played a supporting role. The control system ensured shooting accuracy of 1.7 km. The Titan-1 ICBM carried a monoblock Mk4 warhead detachable in flight with a power of 4–7 Mt.

The missile was based in protected silo launchers and had operational readiness for launch in about 15 minutes. The missile system turned out to be very expensive and vulnerable, especially the tracking and control radar. Therefore, the initially planned number of deployed missiles of this type (108) was reduced by 2 times. They were destined for a short life. They were on combat duty for only three years, and at the end of 1964 the last squad of Titan-1 ICBMs was withdrawn from the SAC.

The abundance of shortcomings and, above all, the low survivability of missile systems with Atlas, Titan-1 and R-7 missiles predetermined their inevitable replacement in the near future. Even during the period of flight tests of these missiles, it became clear to Soviet and American military specialists that it was necessary to create new missile systems.

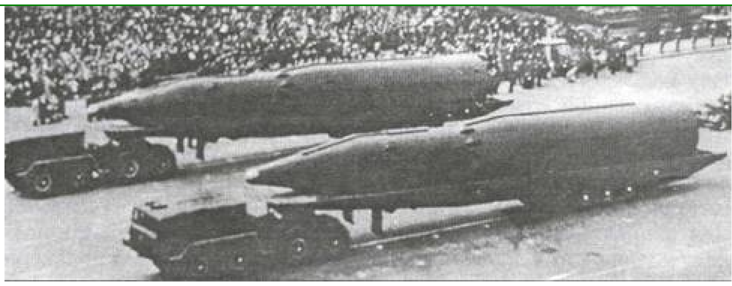
On May 13, 1959, by a special resolution of the CPSU Central Committee and the government, the Design Bureau of Academician Yangel was instructed to develop ICBMs using high-boiling fuel components. Subsequently, it received the designation R-16 (8K64). Design teams headed by V. Glushko, V. Kuznetsov, B. Konoplev and others were involved in the development of rocket engines and systems, as well as at the ground and silo launch positions.



ICBM R-16 (USSR) 1961

Initially, the R-16 was supposed to be launched only from ground launchers. An extremely short time frame was allotted for its design and flight testing.

In the process of preparing the first launch of the rocket on October 23, 1960, after it was refueled with propellant components, a malfunction appeared in the electrical circuit of the propulsion system automation, the elimination of which was carried out on the refueled rocket. Since the guarantee of engine performance after filling the turbopump unit with fuel components was determined in one day, work on preparation for launch and troubleshooting was carried out simultaneously. At the final stage of preparing the rocket for flight, a premature command was sent from the software current distributor to start the second stage engine, as a result of which a fire broke out and the rocket exploded. As a result of the accident, a significant part of the combat crew, a number of senior officials who were at the launch position near the missile, were killed, including the chief designer of the control system B. M. Konoplev, the chairman of the state commission for testing, the commander-in-chief of the Strategic Missile Forces, Chief Marshal of Artillery M. I. Nedelin. The starting position was disabled by the explosion. The causes of the disaster were studied by a government commission and, based on the results of the investigation, a set of measures was outlined and implemented to ensure safety during the development and testing of rocket technology.



ICBM R-16 at the parade

The second launch of the R-16 rocket took place on February 2, 1961. Despite the fact that the rocket fell on the flight path due to loss of stability, the developers were convinced that the adopted scheme was viable. After analyzing the results and eliminating the shortcomings, the tests were continued. Hard work made it possible to complete flight tests of the R-16 from ground launchers by the end of 1961 and in the same year to put the first missile regiment on combat duty.

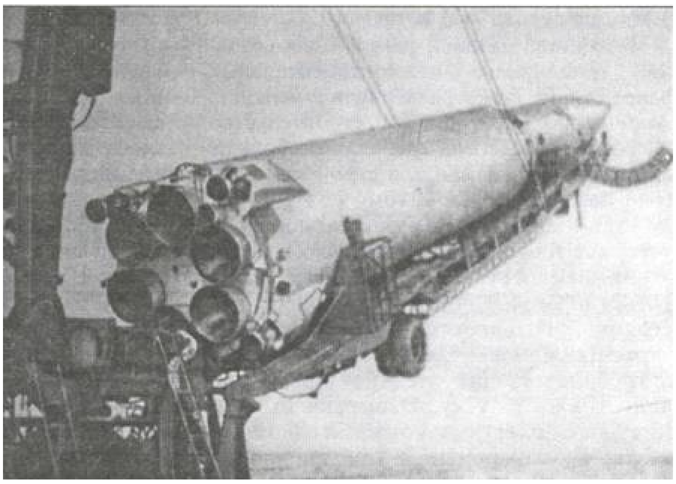
Since May 1960, work has been carried out related to the launch of a modified R-16U (8K64U) missile from a silo launcher. In January 1962, the first missile launch from a silo took place at the Baikonur test site. The following year, the combat missile system with the R-16U ICBM was adopted by the Strategic Missile Forces.

The rocket was made according to the "tandem" design with a sequential separation of stages. The first, accelerating stage consisted of a tail compartment, a fuel tank, an instrument compartment, an oxidizer tank and an adapter. Tanks of the supporting structure were pressurized in flight: the oxidizer tank was pressurized with a counter flow of air, and the fuel tank was pressurized with compressed air from cylinders located in the instrument compartment.

The propulsion system consisted of main and steering engines. The propulsion rocket engine is assembled from three identical two-chamber blocks. Each of them included two combustion chambers, a fuel pump, a gas generator and a fuel supply system. The total thrust of all blocks on the ground is 227 tons, operating time is 90 seconds. The steering rocket engine had four rotary combustion chambers with one turbopump unit. Stage separation was ensured by pyrobolts. Simultaneously with their activation, four braking powder engines located in the first stage were turned on.

The second stage, which served to accelerate the rocket to a speed corresponding to the given flight range, had a similar design as the first, but was made shorter and of smaller diameter. Both tanks were inflated with compressed air.

The propulsion system was largely borrowed from the first stage, which reduced the cost and simplified production, but only one block was installed as the main engine. It developed a vacuum thrust of 90 tons and operated for 125 seconds. The designers managed to successfully solve the problem of reliable launch of a liquid-propellant rocket engine in a rarefied atmosphere, and the main engine was turned on after the separated stage was removed.



Installation of the R-16 ICBM on the launch pad

All rocket engines operated on fuel components that ignited spontaneously on contact. To refuel the rocket with propellant components, supply it to the combustion chambers, store compressed air and distribute it to consumers, the rocket was equipped with a pneumatic hydraulic system.

The R-16 had a secure autonomous control system. It included automatic stabilization, RKS, SOB, and automatic range control systems. For the first time on Soviet missiles, a gyro-stabilized platform on a ball-bearing suspension was used as a sensitive element of the control system. Firing accuracy (CA) was 2.7 km when flying at maximum range. In preparation for launch, the rocket was installed on the launch device so that the stabilization plane was in the firing plane. After this, the tanks were filled with fuel components. The R-16 ICBM was equipped with a detachable monoblock warhead of several types. The so-called light warhead had a power of 3 Mt, and the heavy one - 6 Mt.

The R-16 became the base missile for creating a group of intercontinental missiles of the Strategic Missile Forces. The R-16U was deployed in smaller quantities, since the construction of silo complexes required more time than the commissioning of complexes with ground-based launchers. In addition, in 1964 it became clear that this rocket was morally obsolete. Like all first-generation missiles, these ICBMs could not remain fueled for long. They were kept in constant readiness in shelters or mines with empty tanks and required considerable time to prepare for launch. The survivability of the missile systems was also low. And yet, for its time, the R-16 was a completely reliable and fairly advanced missile.

Let's go back to 1958, in the USA. And not by chance. The first tests of ICBMs with liquid propellant engines aroused concern among the leaders of the missile program regarding the possibility of completing tests in the near future, and the prospects of such missiles raised doubts. Under these conditions, attention was turned to solid fuel. Back in 1956, some US industrial firms began active work on the creation of relatively

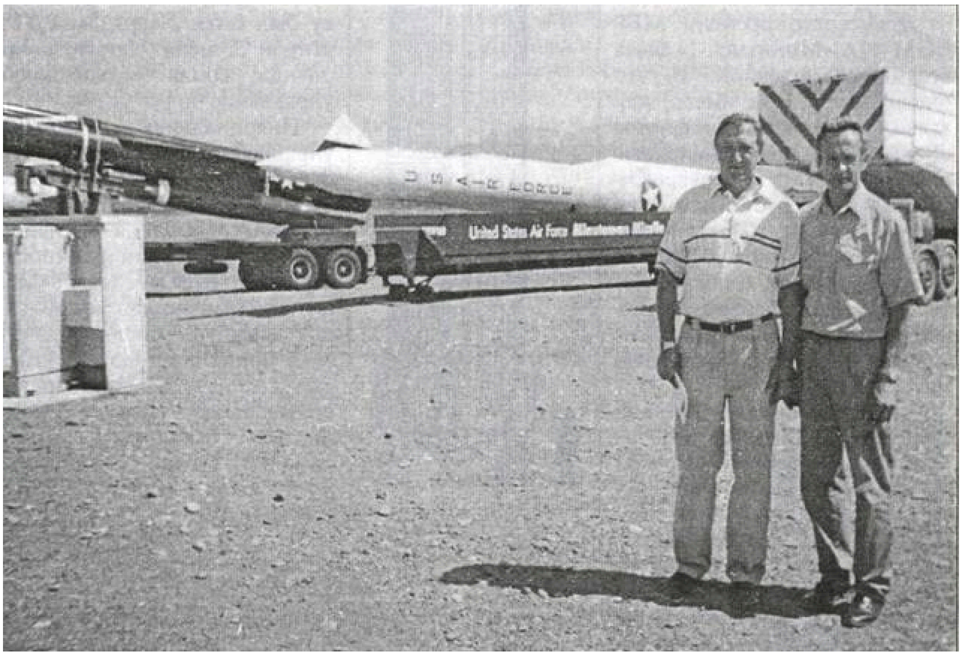
Hall, the former head of the Thor missile program, who was removed from his post, as is known, due to a number of failures in testing this missile, was sent to this group. The active colonel, wanting to rehabilitate himself, after a deep study of the materials, prepared a project for a new missile system, which promised tempting prospects if implemented. General Schriever liked the project and asked management for $150 million for its development. The proposed missile system received the code WS-133A and the name “Minuteman”. But the Air Force Ministry authorized the allocation of only 50 million to finance the first stage, which involved mainly theoretical research. There is nothing surprising. At that time in the United States, there were many high-ranking military leaders and politicians who doubted the possibility of quickly implementing such a project, which was more based on optimistic ideas that had not yet been tested in practice.

Having been refused a full appropriation, Schriever developed a vigorous activity and eventually achieved the allocation of a round sum in 1959 - $184 million. Schriever was not going to take risks with the new rocket, as he had done before, and did everything not to repeat the sad experience. At his insistence, Colonel Otto Glaser was appointed head of the Minuteman project, who by that time had proven himself to be a capable organizer, a member of the scientific community and influential circles of the military-industrial complex. Such a person was very necessary, since having approved the creation of a new missile system, the leadership of the US Department of Defense set strict requirements - to enter flight tests at the end of 1960 and ensure the adoption of the system in 1963.

The work unfolded on a wide front. Already in July 1958, the composition of the development companies was approved, and in October the Boeing company was appointed as the lead company for assembly, installation and testing. In April-May of the following year, the first full-scale tests of the rocket stages were carried out. To speed up their development, it was decided to involve several companies: Thiokol Chemical Corporation developed the first stage, Aerojet General Corporation developed the second stage, and Hercules Powder Corporation developed the third stage. All stage tests were successful.

In early September of the same year, the Senate declared the Minuteman missile system program the highest national priority, which entailed an additional allocation of $899.7 million for its implementation. But despite all the measures, it was not possible to begin flight tests at the end of 1960. The first test launch of the Minuteman-1A ICBM took place on February 1, 1961. And immediately good luck. At that time, this fact was a “fantastic success” for American rocketry. There was a huge uproar about this. Newspapers touted the Minuteman missile system as the embodiment of US technical superiority. The information leak was not accidental. It was used as a means of intimidating the Soviet Union, relations with which the United States of America had sharply deteriorated primarily because of Cuba.

However, the real situation was not so rosy. Back in 1960, before the start of flight tests, it became clear that the Minuteman-1 A would not be able to fly at a range of over 9,500 km. Subsequently, tests confirmed this assumption. In October 1961, the developers began work on improving the rocket in order to increase the flight range and power of the warhead. Later this modification received the designation “Minuteman-1B”. But they also did not intend to abandon the deployment of A-series missiles. At the end of 1962, it was decided to place 150 of them on combat duty at the Malstrom Air Force Missile Base, Montana.

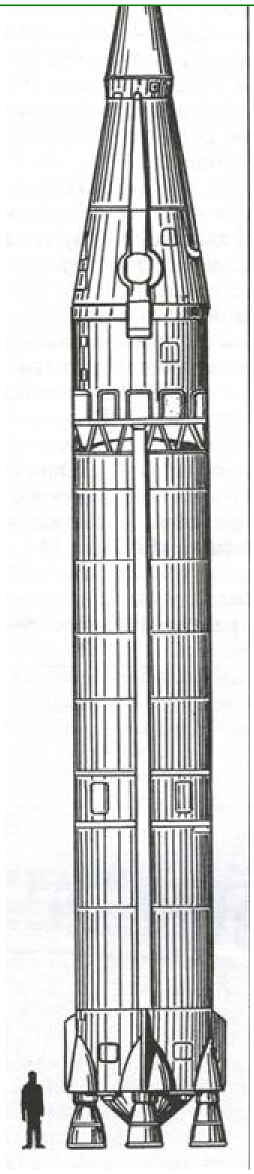


Minuteman 1B ICBM and missile installer

At the beginning of 1963, testing of the Minuteman-1B ICBM was completed and at the end of that year it began to enter service. By July 1965, the creation of a group of 650 missiles of this type was completed. The Minuteman 1 missile was tested at the Western Missile Range (Vandenberg Air Force Base). In total, taking into account combat training launches, 54 missiles of both modifications were launched.

For its time, the LGM-30A Minuteman 1 ICBM was very advanced. And what is very important, it had, as a Boeing representative said, “...unlimited opportunities for improvement.” This was not empty bravado, and the reader will be able to see this below. The three-stage rocket, with sequential separation of stages, was made of materials that were modern for that time.

The first stage engine housing was made of special steel with high purity and strength. A coating was applied to its inner surface, ensuring connection between the housing and the fuel charge. It also served as thermal protection, which made it possible to compensate for changes in fuel volume when the charge temperature fluctuated. The M-55 solid propellant rocket engine had four rotating nozzles. It developed a thrust on the ground of 76 tons. Its operating time was 60 seconds. Mixed fuel consisting of ammonium perchlorate, polybutadiene copolymer, acrylic acid, epoxy resin and powdered aluminum. The filling of the charge into the housing was controlled by a special computer.



ICBM R-9A (USSR) 1965

The second stage engine had a titanium alloy housing. A charge of polyurethane-based mixed fuel was poured into the housing. A similar stage of the Minuteman-1B rocket had a slightly larger charge. Four rotating nozzles provided flight control. The M-56 solid propellant rocket engine developed a thrust in vacuum of 27 tons.

The third stage engine had a fiberglass casing. It developed a thrust of 18.7 tons. Its duration of operation was about 65 seconds. The fuel charge was similar in composition to the charge of the second stage solid propellant rocket engine. Four rotating nozzles provided control at all angles.

An inertial control system, built on the basis of a sequential computer, provided control of the missile’s flight in the active part of the trajectory and a firing accuracy of 1.6 km. "Minuteman-1 A" carried a monoblock nuclear warhead Mk5 with a yield of 0.5 Mt, which was aimed at a predetermined target. "Minuteman-1B" was equipped with a monoblock nuclear warhead Mk11 with a capacity of 1 Mt. Before launch, it could have been aimed at one of two possible targets. The missiles were stored in silo launchers and could be launched within a minute after the launch command was received from the detachment's control point. The first stage propulsion engine was started directly in the shaft, and in order to reduce the heating of the body by hot gases, it was coated on the outside with special protective paint.

The presence of such a missile system in service significantly increased the potential of US nuclear forces, and also created conditions for launching a surprise nuclear strike on the enemy. Its appearance caused great concern among the Soviet leadership, since the R-16 ICBM, with all its advantages, was clearly inferior to the American missile in terms of survivability and combat readiness, and the R-9A (8K75) ICBM being developed at OKB-1 has not yet passed flight tests. It was created in accordance with a government decree of May 13, 1959, although individual work on the design of such a rocket began much earlier.

The beginning of flight design tests of the R-9 (S.P. Korolev was present at the first launch on April 9, 1961) cannot be called completely successful. The lack of development of the first stage liquid-propellant rocket engine had an effect - strong pressure pulsations in the combustion chamber failed. He was put on the rocket under pressure from V. Glushko. Although the propulsion systems for this rocket were decided to be created on a competitive basis, the head of the GDL-OKB could not lower the prestige of his team, which was considered the leader in engine building.

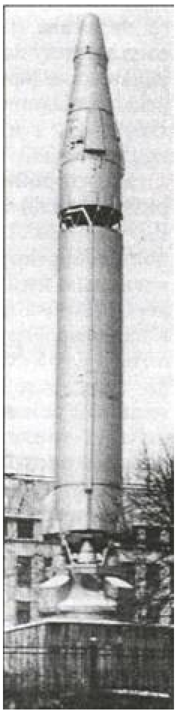
This was the reason for the explosions during the first launches. Design teams led by A. Isaev and N. Kuznetsov also took part in the competition. As a result of the curtailment of the aircraft engine construction program, the latter's design bureau was left with virtually no orders. Kuznetsov's liquid-propellant rocket engine was built according to a more advanced closed circuit with afterburning of exhaust turbogas in the main combustion chamber. In the liquid rocket engines of Glushko and Isaev, created according to an open design, the gas exhausted in the turbopump unit was discharged through the exhaust pipe into the atmosphere. The work of all three design bureaus reached the stage of bench testing, but the competitive selection did not work out. The “lobbying” approach of the Glushko Design Bureau still prevailed.

a problem on which the very possibility of the "nine" being on combat duty depended. We are talking about methods for long-term storage of large quantities of liquid oxygen to refuel rocket tanks. As a result, a system was created that ensured oxygen loss of no more than 2–3% per year.

Flight tests were completed in February 1964, and on July 21, 1965, the missile, designated R-9A, was put into service and remained on combat duty until the second half of the 70s.

Structurally, the R-9A was divided into the first stage, which consisted of a tail compartment of the propulsion system with nozzle fairings and short stabilizers, supporting cylindrical fuel and oxidizer fuel tanks and a truss adapter. The control system devices were "embedded" into the shell of the intertank compartment.

The "Nine" was distinguished by a relatively short operating period of the first stage, as a result of which the separation of the stages occurred at an altitude where the influence of the velocity pressure on the rocket was still significant. The so-called "hot" stage separation method was implemented on the rocket, in which the second stage engine was started at the end of the first stage propulsion engine. In this case, hot gases flow through the truss structure of the adapter. Due to the fact that at the moment of separation the second stage rocket engine operated at only 50% of the rated thrust and the short second stage was aerodynamically unstable, the steering nozzles could not cope with the disturbing moments. To eliminate this drawback, the designers installed special aerodynamic flaps on the outer surface of the jettisonable tail compartment, the opening of which, when the stages were separated, shifted the center of pressure and increased the stability of the rocket. After the liquid-propellant rocket engine reached the operating thrust mode, the fairing of the tail section along with these flaps was dropped.



ICBM R-9A (USSR) 1965

With the advent in the United States of systems for detecting ICBM launches using a powerful engine torch, a short period of operation of the first stage became an advantage of the "nine". After all, the shorter the torch's lifetime, the more difficult it is for missile defense systems to respond to such a missile. The R-9A had engines running on oxygen-kerosene fuel. It was precisely this fuel that S. Korolev paid special attention to as non-toxic, high-energy and cheap to produce.

At the first stage there was a four-chamber RD-111 with exhaust of waste steam gas from the TNA through a fixed nozzle between the chambers. To ensure rocket control, the cameras were made to swing. The engine developed a thrust of 141 tons and operated for 105 seconds.

At the second stage, a four-chamber liquid propellant engine with RD-461 steering nozzles designed by S. Kosberg was installed. It had a record specific impulse for that time among oxygen-kerosene engines and developed a thrust in vacuum of 31 tons. The maximum operating time was 165 seconds. To quickly bring the propulsion systems to nominal mode and ignite the fuel components, a special starting system with pyroignition devices was used.

The missile was equipped with a combined control system that ensured firing accuracy (CAO) at ranges over 12,000 km and no more than 1.6 km. On the R-9A, the radio technical channel was eventually abandoned.

For the R-9A ICBM, two versions of monoblock nuclear warheads were developed: standard and heavy, weighing 2.2 tons. The first had a power of 3 Mt and could be delivered to a range of over 13,500 km, the second - 4 Mt. With it, the missile's flight range reached 12,500 km.

As a result of the introduction of a number of technical innovations, the rocket turned out to be compact, suitable for launch from both ground and silo launchers. The rocket, launched from a ground launcher, additionally had an adapter frame, which was attached to the tail section of the first stage.

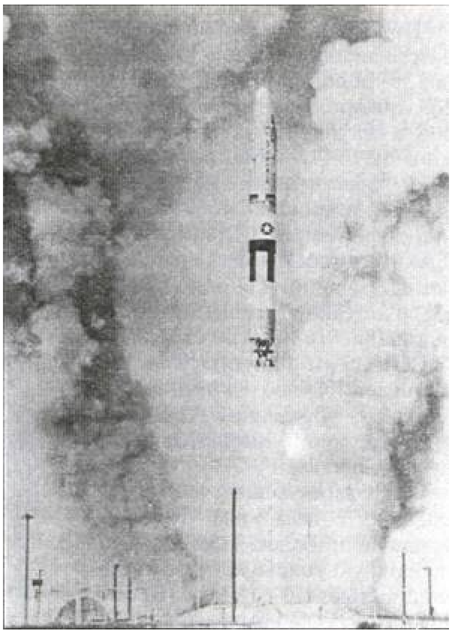
Despite its advantages, by the time the first missile regiment was put on combat duty, the "nine" no longer fully satisfied the set of requirements for combat strategic missiles. And it is not surprising, since it belonged to the first generation ICBMs and retained their inherent features. While superior to the American Titan-1 ICBM in combat, technical and operational characteristics, it was inferior to the latest Minutemen in terms of shooting accuracy and launch preparation time, and these indicators became decisive by the end of the 60s. The R-9A became the last combat missile to use oxygen-kerosene fuel.

The rapid development of electronics in the early 60s opened up new horizons for the development of military systems for various purposes. For rocket science, this factor was of great importance. An opportunity has arisen to create more advanced missile control systems capable of ensuring high hit accuracy, largely automating the operation of missile systems, and most importantly, automating centralized combat control systems capable of ensuring guaranteed delivery of launch orders to ICBMs, coming only from the high command (president) and exclude the unauthorized use of nuclear weapons.

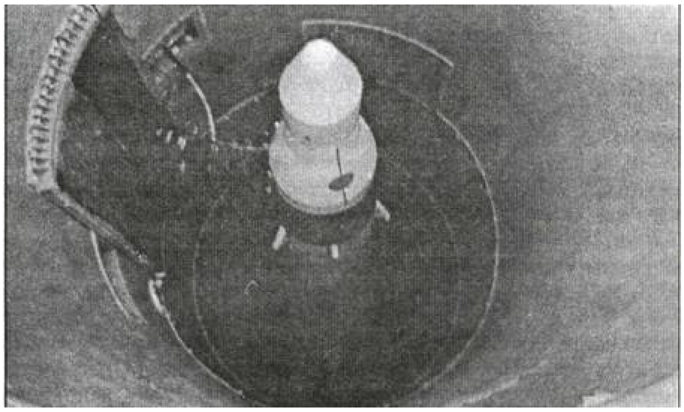
1960, the designers of the Martin company began modernizing the rocket, and at the same time creating a new launch complex.

Flight development tests that began in March 1962 confirmed the correctness of the chosen technical strategy. In many ways, the rapid progress of work was facilitated by the fact that the new ICBM inherited much from its predecessor. In June of the following year, the Titan-2 missile was accepted into service with the strategic nuclear forces, although control and combat training launches were still ongoing. In total, from the beginning of testing to April 1964, 30 launches of missiles of this type were carried out at various ranges from the Western Missile Test Site. The Titan-2 missile was intended to destroy the most important strategic targets. Initially, it was planned to put 108 units on duty, replacing all Titan-1s. But plans changed, and as a result they limited themselves to 54 missiles.

Despite the close relationship, the Titan-2 ICBM had many differences from its predecessor. The method of pressurizing fuel tanks has changed. The oxidizer tank at the first stage was pressurized with nitrogen tetroxide gas, the fuel tanks of both stages were pressurized with cooled generator gas, the oxidizer tank of the second stage had no pressurization at all. When the engine of this stage was operating, constant thrust was ensured by maintaining a constant ratio of fuel components in the gas generator using Venturi nozzles installed in the fuel supply lines. The fuel was also changed. Stable aerosin-50 and nitrogen tetroxide were used to power all liquid-propellant rocket engines.



Titan-2 ICBM in flight



ICBM "Minuteman-2" in silo

At the first stage, a modernized two-chamber LR-87 rocket engine with a thrust on the ground of 195 tons was installed. Its turbopump unit was spun up using a powder starter. The LR-91 second-stage propulsion rocket engine has also undergone modernization. Not only its thrust has increased (up to 46 tons), but also the degree of expansion of the nozzle. In addition, two steering solid propellant rocket engines were installed in the tail section.

Fire separation of stages was used on the rocket. The second-stage propulsion engine was turned on when the pressure in the combustion chambers of the liquid-propellant rocket engine dropped to 0.75 nominal, which gave a braking effect. At the moment of separation, two braking engines were turned on. When the head part was separated from the second stage, the latter was braked by three brake solid propellant rocket engines and moved to the side.

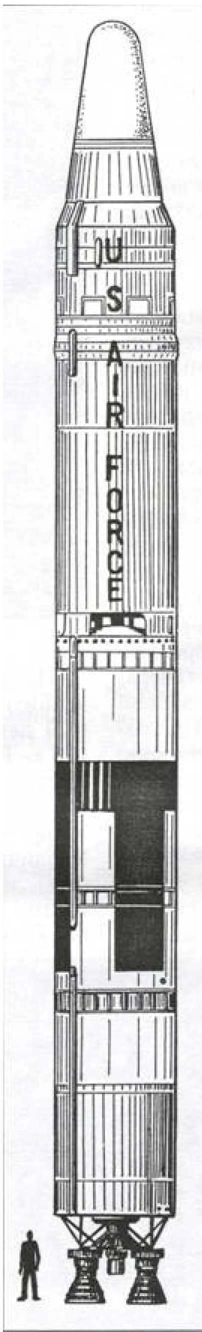
The flight of the rocket was controlled by an inertial control system with a small-sized GPS and a digital computer, performing 6000 operations per second. A lightweight magnetic drum with a capacity of 100,000 units of information was used as a storage device, which made it possible to store several flight missions for one rocket in memory. The control system ensured a firing accuracy of 1.5 km and automatic execution, upon command from the control point, of the pre-launch preparation and launch cycle.

Due to the increase in throw weight, a heavier monoblock Mkb warhead with a capacity of 10–15 Mt was installed on the Titan-2. In addition, it carried a set of passive means of overcoming missile defense.

the order.

Before the advent of the Soviet R-36 missile, the Titan-2 intercontinental ballistic missile was the most powerful in the world. She remained on combat duty until 1987. The modified Titan-2 rocket was also used for peaceful purposes to launch various spacecraft into orbit, including the Gemini spacecraft. On its basis, various versions of the Titan-3 launch vehicles were created.

The Minuteman missile system also received further development. This decision was preceded by the work of a special Senate commission, whose task was to determine the further and, if possible, more economical path for the development of strategic weapons for the United States. The commission's conclusions stated that it was necessary to develop the ground component of the American strategic nuclear forces based on the Minuteman missile.



Titan-2 ICBM (USA) 1963

In July 1962, Boeing received an order to develop the LGM-30F Minuteman 2 rocket. To meet customer requirements, the designers needed to create a new second stage and control system. But a missile system is not just a rocket. It was necessary to significantly modernize ground-based technological and technical equipment, command post systems and launchers. At the end of the summer of 1964, the new ICBM was ready for flight tests. On September 24, the first launch of the Minuteman-2 ICBM was carried out from the Western Missile Range. The entire range of tests was completed within a year, and in December 1965, deployment of these missiles began at the Grand Forks Air Force Base, North Dakota. In total, taking into account the combat training launches carried out by regular crews to gain experience in combat use, during the period from September 1964 to the end of 1967, 46 launches of ICBMs of this type took place from the Vandenberg base.

On the Minuteman 2 rocket, the first and third stages were no different from the similar stages of the Minuteman 1 B rocket, but the second was completely new. Aerojet General Corporation has developed the SR-19 solid propellant rocket engine with a vacuum thrust of 27 tons and an operating time of up to 65 seconds. The engine housing was made of titanium alloy. The use of polybutadiene-based fuel made it possible to obtain a higher specific impulse. To achieve the specified firing range, the fuel supply had to be increased by 1.5 tons. Since the rocket engine now had only one fixed nozzle, designers had to develop new ways to generate control forces.

angle were implemented by four small jet nozzles, which were built into the engine body. Their functioning was ensured by a powder pressure accumulator. The freon supply was stored in a toroidal tank placed on the top of the nozzle.

An inertial control system with a universal digital computer assembled on microcircuits was installed on the rocket. All gyroscopes of the sensitive elements of the GPS were in a spin-up state, which made it possible to maintain the rocket in a very high readiness for launch. The excess heat released during this process was removed by a temperature control system. Hydroblocks could operate in this mode continuously for 1.5 years, after which they had to be replaced. The magnetic disk storage device provided storage of eight flight missions designed for various targets.

When the missile was on combat duty, its control system was used to carry out checks, calibrate on-board equipment and other tasks solved in the process of maintaining combat readiness. When firing at maximum range, it ensured a shooting accuracy of 0.9 km.

"Minuteman-2" was equipped with a monoblock nuclear warhead Mk11 of two modifications, differing in charge power (2 and 4 Mt). The missile was successfully equipped with means to overcome missile defense.

By the beginning of 1971, the entire Minuteman-2 ICBM group was fully deployed. Initially, it was planned to supply the Air Force with 1000 missiles of this type (upgrade 800 Minuteman-1A(B) missiles and build 200 new ones). But the military department had to reduce requests. As a result, only half (200 new and 300 modernized) missiles were put on combat duty.

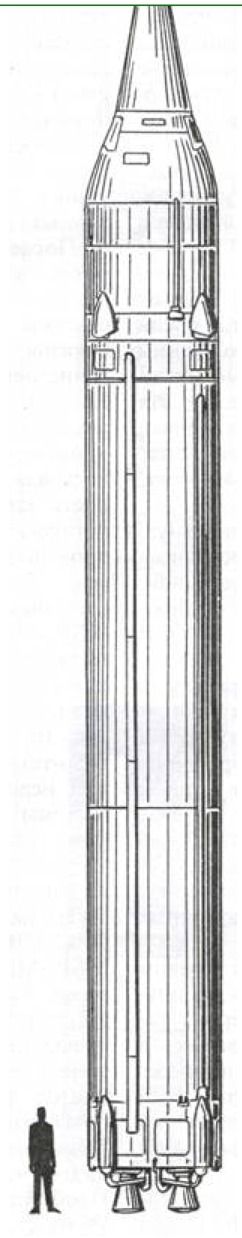
After the Minuteman-2 missiles were installed in the launch silos, the first checks revealed failures of the on-board control system. The flow of such failures increased noticeably and the only repair base in the city of Newark could not cope with the volume of repair work due to limited production capabilities. For these purposes, it was necessary to use the capacity of the Otonetics manufacturing plant, which immediately affected the rate of production of new missiles. The situation became even more complicated when modernization of the Minuteman-1B ICBM began at missile bases. The reason for this phenomenon, which was very unpleasant for the Americans, which also resulted in a delay in the deployment of the entire group of missiles, was that even at the stage of developing tactical and technical requirements, an insufficient level of reliability of the control system was laid down. It was only possible to cope with requests for repairs by October 1967, which of course required additional financial expenses.

At the beginning of 1993, the US strategic nuclear forces included 450 deployed Minuteman-2 ICBMs and 50 missiles in reserve. Naturally, over its long service life, the missile was modernized in order to increase its combat capabilities. Improvement of some elements of the control system made it possible to increase the firing accuracy to 600 m. The fuel charges in the first and third stages were replaced. The need for such work was caused by the aging of the fuel, which affected the reliability of the rockets. The protection of launchers and command posts of missile systems was increased.

Over time, such an advantage as a long service life turned into a disadvantage. The thing is that the existing cooperation of companies involved in the production of missiles and components for them at the development and deployment stage began to disintegrate. Periodic updating of various missile systems required the manufacture of products that had not been produced for a long time, and the costs of maintaining a group of missiles in combat-ready condition were steadily increasing.

In the USSR, the first second-generation ICBM to be equipped with the Strategic Missile Forces was the UR-100 missile, developed under the leadership of Academician Vladimir Nikolaevich Chelomey. The task was issued to the team he led on March 30, 1963, by a corresponding government decree. In addition to the head design bureau, a significant number of related organizations were involved, which made it possible to work out all the systems of the missile complex being created in a short time. In the spring of 1965, flight tests of the rocket began at the Baikonur test site. On April 19, a launch took place from a ground launcher, and on July 17, the first launch from a silo took place. The first tests showed that the propulsion system and control system were incomplete. However, eliminating these shortcomings did not take much time. On October 27 of the following year, the entire flight test program was completely completed. On November 24, 1966, the combat missile system with the UR-100 missile was adopted by the missile regiments.

The UR-100 ICBM was made according to the "tandem" design with sequential separation of stages. The fuel tanks of the supporting structure had a combined bottom. The first stage consisted of a tail section, a propulsion system, fuel and oxidizer tanks. The propulsion system included four propulsion rocket engines with rotary combustion chambers, made in a closed circuit. The engines had a high specific thrust impulse, which made it possible to limit the operating time of the first stage.



ICBM PC-10 (USSR) 1971

The second stage is similar in design to the first, but smaller in size. Its propulsion system consisted of two rocket engines: a single-chamber propulsion engine and a four-chamber steering engine.

To increase the energy capabilities of the engines, ensure refueling and draining of rocket fuel components, the rocket had a pneumatic-hydraulic system. Its elements were placed on both steps. Nitrogen tetroxide and unsymmetrical dimethylhydrazine, which self-ignite upon mutual contact, were used as fuel components.

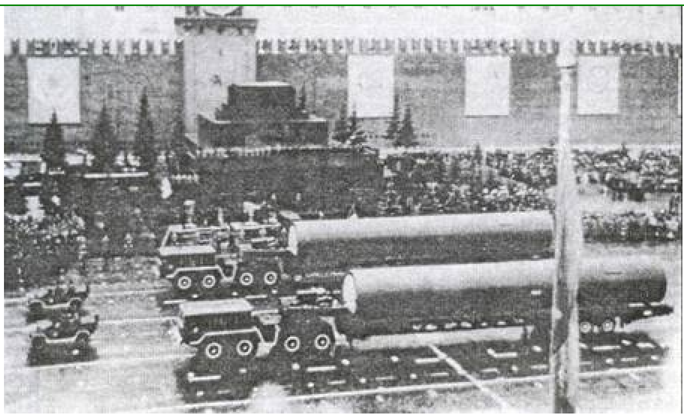
An inertial control system was installed on the rocket, which ensured a firing accuracy of 1.4 km. Its component subsystems were distributed throughout the rocket. The UR-100 carried a monoblock warhead with a nuclear charge of 1 Mt that separated in flight from the second stage.

The great advantage was that the rocket was ampulized (isolated from the external environment) in a special container in which it was transported and stored in a silo launcher for several years in constant readiness for launch. The use of diaphragm valves separating fuel tanks with aggressive components from rocket engines made it possible to keep the rocket constantly fueled. The rocket launched directly from the container. Monitoring the technical condition of the missiles of one combat missile system, as well as pre-launch preparation and launch, were carried out remotely from a single command post.

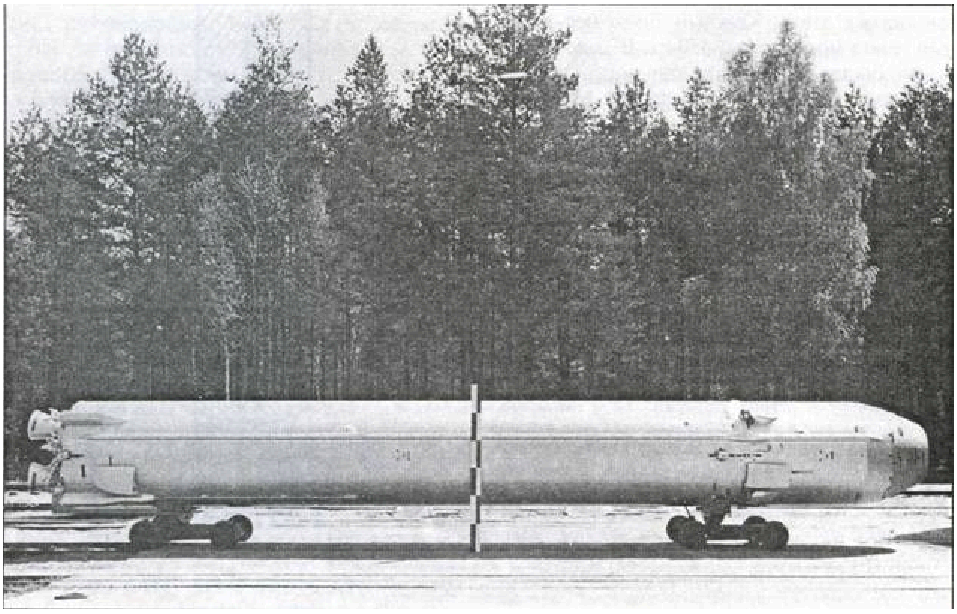
The UR-100 ICBM was further developed in a number of modifications. In 1970, UR-100 UTTH missiles began to enter service, which had a more advanced control system, a more reliable warhead and a set of means to overcome missile defense.

Even earlier, on July 23, 1969, flight tests of another modification of this missile, which received the military designation UR-100K (RS-10), began at the Baikonur test site. They ended on March 15, 1971, after which the replacement of UR-100 missiles began.

The new missile was superior to its predecessors in shooting accuracy, reliability and performance characteristics. The propulsion systems of both stages were modified. The service life of liquid-propellant rocket engines has been increased, as well as their reliability. A new transport and launch container was developed. Its design has become more rational and convenient, which has made it easier to maintain the rocket and reduce the time of routine maintenance by three times. The installation of new control equipment made it possible to fully automate the cycle of checking the technical condition of missiles and launcher systems. The security of missile complex structures has increased.



ICBM UR-100 in TPK at the parade

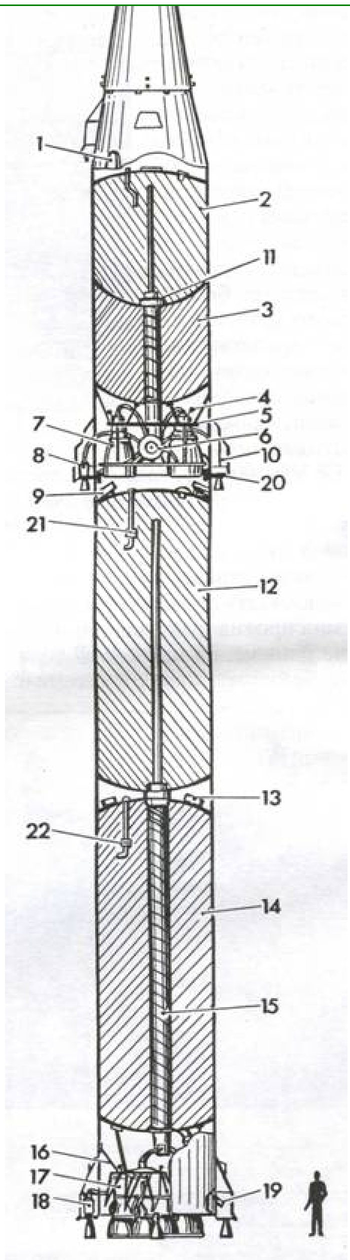


ICBM PC-10 assembled without warhead (outside the launch container)

For the beginning of the 70s, the rocket had high combat characteristics and reliability. The flight range was 12,000 km, the accuracy of delivery of the monoblock warhead of the megaton class was 900 m. All this determined its long service life, which was extended more than once by the commission of the chief designer: the combat missile system with the UR-100K missile, adopted by the Strategic Missile Forces in October 1971, was in service duty until 1994. In addition, the PC-10 family became the most popular of all Soviet ICBMs.

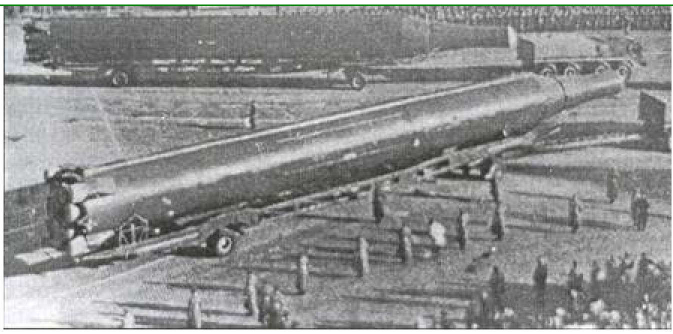
On June 16, 1971, the latest modification of this family, the UR-100U rocket, took off from Baikonur on its first flight. It was equipped with a warhead with three dispersible warheads. Each block carried a nuclear charge with a power of 350 kt. During the tests, a flight range of 10,500 km was achieved. At the end of 1973, this ICBM entered service.

The next second-generation ICBM to be equipped with the Strategic Missile Forces was the R-36 (8K67), the ancestor of Soviet heavy missiles. By a government decree of May 12, 1962, Academician Yangel's design bureau was tasked with creating a rocket capable of significantly supporting the ambitions of N. S. Khrushchev. It was intended to destroy the enemy’s most important strategic targets protected by missile defense systems. The technical specifications provided for the creation of a rocket in two versions, which were to differ in launching methods: with a ground launch (like the American Atlas) and with a silo launch, like the R-16U. The unpromising first option was quickly abandoned. Nevertheless, the rocket was developed in two versions. But now they differed in the principle of constructing a control system. The first rocket had a purely inertial system, and the second had an inertial system with radio correction. When creating the complex, special attention was paid to the maximum simplification of the launch positions, which were developed by the design bureau under the leadership of E. G. Rudyak: their reliability was increased, missile refueling was excluded from the launch cycle, remote control of the main parameters of the missile and systems was introduced during combat duty and preparation for launch and remote rocket launch.



ICBM R-36 (USSR) 1967

1 - upper part of the cable box; 2 — second stage oxidizer tank; 3 — second stage fuel tank; 4 — pressure sensor of the traction control system; 5 — frame for attaching engines to the body; 6 — turbopump unit; 7 — liquid-propellant rocket engine nozzle; 8 — steering rocket engine of the second stage; 9 — first stage braking powder engine; 10 — protective fairing of the steering motor; 11 — intake device; 12 — first stage oxidizer tank; 13 — rocket control system unit located on the first stage; 14 — first stage fuel tank; 15 — protected oxidizer supply pipeline; 16 — fastening the liquid-propellant rocket engine frame to the body of the tail section of the first stage; 17—LPRE combustion chamber; 18 — first stage steering motor; 19 — drainage pipe; 20 — pressure sensor in the fuel tank; 21 — pressure sensor in the oxidizer tank.



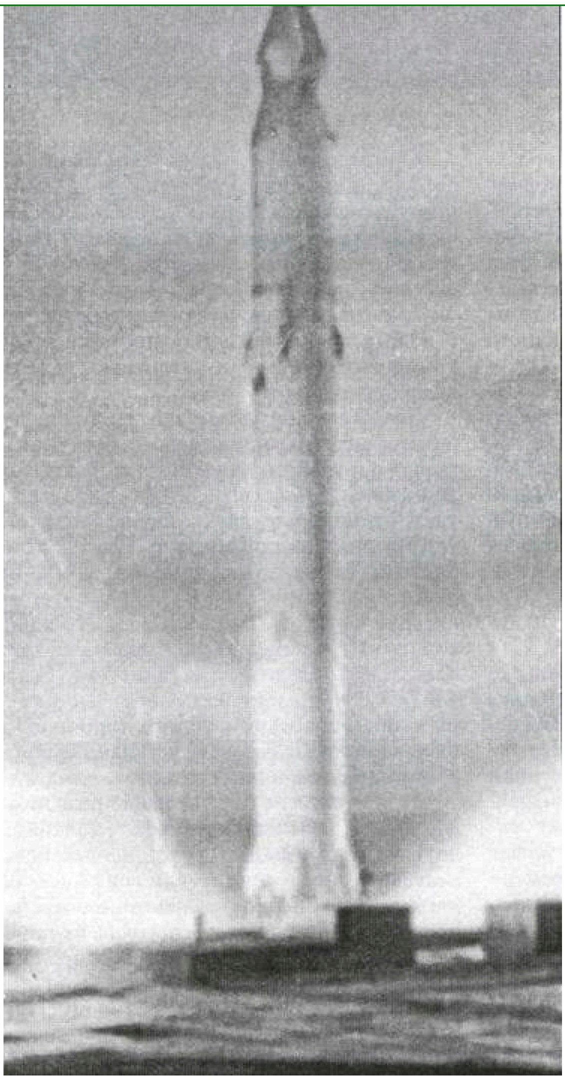
ICBM R-36 at the parade

The tests were carried out at the Baikonur test site. On September 28, 1963, the first launch took place, which ended unsuccessfully. Despite the initial malfunctions and failures, members of the state commission under the leadership of Lieutenant General M. G. Grigoriev recognized the rocket as promising and had no doubt about its ultimate success. The system of testing and testing the missile system adopted by that time made it possible, simultaneously with flight tests, to launch serial production of missiles, technological equipment, as well as the construction of launch positions. At the end of May 1966, the entire test cycle was completed, and on July 21 of the following year, the DBK with the R-36 ICBM was put into service.

The two-stage R-36 is made according to the "tandem" design from high-strength aluminum alloys. The first stage provided acceleration of the rocket and consisted of a tail section, a propulsion system and supporting fuel tanks of fuel and oxidizer. The fuel tanks were inflated in flight with combustion products of the main components and had devices for damping vibrations.

The propulsion system consisted of a six-chamber propulsion and four-chamber steering liquid rocket engines. The propulsion rocket engine was assembled from three identical two-chamber blocks mounted on a common frame. The supply of fuel components to the combustion chambers was provided by three TNAs, the turbines of which were spun by the products of fuel combustion in the gas generator. The total thrust of the engine at the ground was 274 tons. The steering rocket engine had four rotary combustion chambers with one common turbopump unit. The cameras were installed in the "pockets" of the tail compartment.

The second stage ensured acceleration to a speed corresponding to the specified firing range. Its fuel tanks of a supporting structure had a combined bottom. The propulsion system located in the tail compartment consisted of a two-chamber main and four-chamber steering liquid rocket engines. The RD-219 propulsion rocket engine is largely similar in design to the first stage propulsion units. The main difference was that the combustion chambers were designed for a greater degree of gas expansion and their nozzles also had a greater degree of expansion. The engine included two combustion chambers, a fuel pump feeding them, a gas generator, automation units, an engine frame and other elements. It developed a vacuum thrust of 101 tons and could operate for 125 seconds. The steering motor was no different in design from the engine installed on the first stage.



ICBM R-36 at launch

All liquid-propellant rocket engines were developed by GDL-OKB designers. To power them, a two-component fuel self-igniting on contact was used: the oxidizer was a mixture of nitrogen oxides with nitric acid, and the fuel was asymmetrical dimethylhydrazine. To refuel, drain and supply fuel components to rocket engines, a pneumatic hydraulic system was installed on the rocket.

The stages were separated from each other and the head part by firing explosive bolts. To avoid collisions, braking of the separated stage was provided due to the activation of braking powder engines.

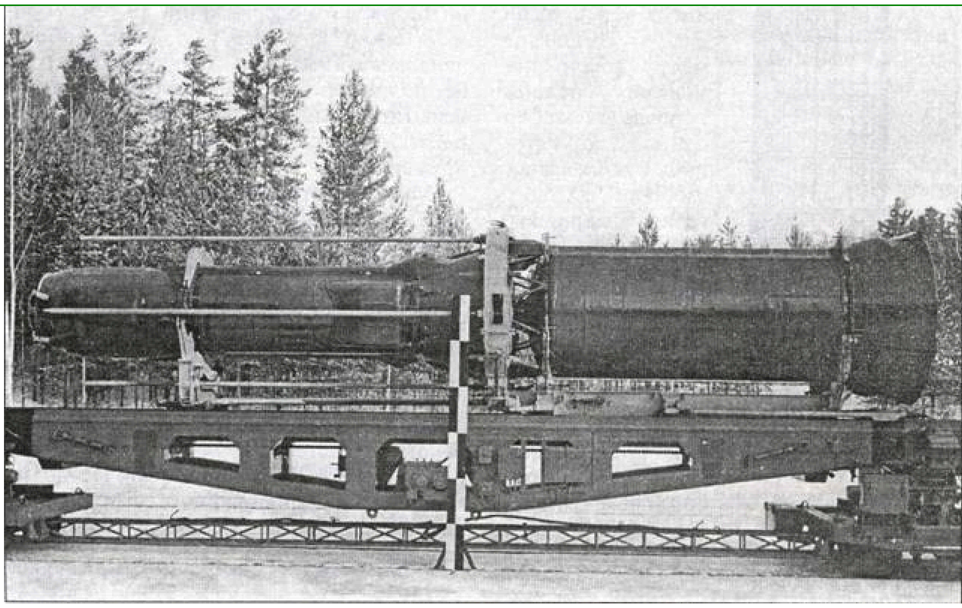
A combined control system was developed for the R-36. The autonomous inertial system provided control in the active part of the trajectory and included a stabilization automatic, a range automatic, a security system that ensured the simultaneous production of oxidizer and fuel from the tanks, and a system for turning the rocket after launch to the designated target. The radio control system was supposed to correct the movement of the rocket at the end of the active section. However, during flight tests it became clear that the autonomous system ensures the specified shooting accuracy (CEP of about 1200 m) and the radio system was abandoned. This made it possible to significantly reduce financial costs and simplify the operation of the missile system.

The R-36 ICBM was equipped with a monoblock thermonuclear warhead of one of two types: a light one with a power of 18 Mt and a heavy one with a power of 25 Mt. To overcome the enemy's missile defense, a reliable set of special equipment was installed on the missile. In addition, there was a system for emergency destruction of the warhead, which was triggered when the movement parameters on the active part of the trajectory deviated beyond the permissible limits.

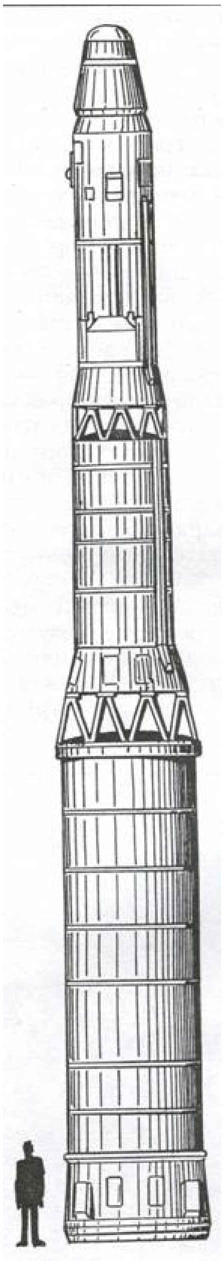
The missile was launched automatically from a single silo, where it was stored in a fueled state for 5 years. A long service life was achieved by sealing the rocket and creating optimal temperature and humidity conditions in the shaft. The DBK with the R-36 had unique combat capabilities and was significantly superior to the American complex of a similar purpose with the Titan-2 missile, primarily in terms of nuclear charge power, shooting accuracy and security.

The last of the Soviet missiles of this period to enter service was the PC-12 combat solid-fuel ICBM. But long before that, in 1959, in the design bureau headed by S.P. Korolev, the development of an experimental rocket with solid fuel engines, designed to destroy objects in the medium range, began. Based on the results of tests of the units and systems of this rocket, the designers concluded that it was possible to create an intercontinental missile. A discussion ensued between supporters and opponents of this project. At that time, Soviet technology for creating large mixed charges was just in its infancy, and naturally there were doubts about its ultimate success. Everything was too new. The decision to create a solid-fuel rocket was made at the very top. Not the least role was played by news from the United States about the start of testing ICBMs using mixed solid fuel. On April 4, 1961, a government decree was issued, in which the Korolev Design Bureau was appointed as the lead in creating a fundamentally new stationary combat missile system with an intercontinental solid-fuel missile equipped with a monoblock warhead. Many research organizations and design bureaus were involved in solving this problem. To test intercontinental missiles and implement a number of other programs, on January 2, 1963, a new Plesetsk test site was created.

In the process of developing the missile system, complex scientific, technical and production problems had to be solved. Thus, mixed solid fuels and large-sized engine charges were developed and the technology for their production was mastered. A fundamentally new management system has been created. A new type of launcher was developed that ensures the launch of a rocket on a main engine from a blind launch cup.



RS-12, second and third stages without warhead



The first launch of the RT-2P rocket took place on November 4, 1966. The tests were carried out at the Plesetsk test site under the guidance of a state commission. It took exactly two years to completely dispel all doubts of skeptics. On December 18, 1968, the missile system with this missile was adopted by the Strategic Missile Forces.

The RT-2P rocket had three stages. To connect them together, connecting compartments of a truss structure were used, which allowed the gases of the main engines to freely escape. The engines of the second and third stages were turned on a few seconds before the pyrobolts were activated.

The rocket engines of the first and second stages had steel casings and nozzle blocks consisting of four split control nozzles. The third stage rocket engine differed from them in that it had a body of mixed design. All engines were made in different diameters. This was done in order to ensure the specified flight range. To launch solid propellant rocket engines, special igniters were used, mounted on the front bottoms of the hulls.

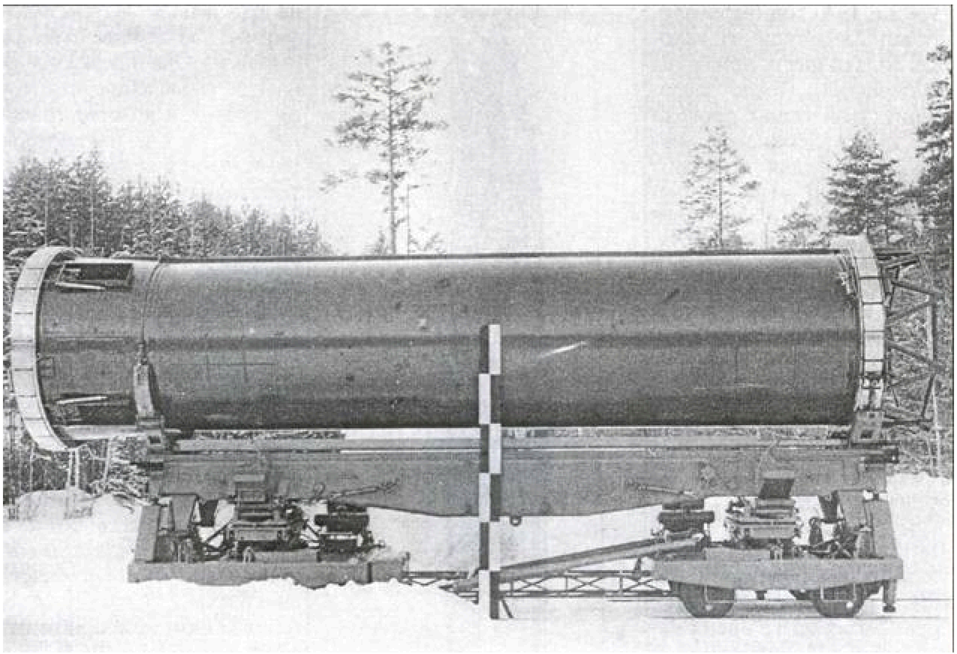
The missile control system is autonomous inertial. It consisted of a set of instruments and devices that controlled the movement of the rocket in flight from the moment of launch until the transition to the uncontrolled flight of the warhead. The control system used computers and pendulum accelerometers. The elements of the control system were located in the instrument compartment installed between the head part and the third stage, and its executive bodies were located at all stages in the tail compartments. The shooting accuracy was 1.9 km.

The ICBM carried a monoblock nuclear charge with a yield of 0.6 Mt. Monitoring the technical condition and launching the missiles was carried out remotely from the DBK command post. The important features of this complex for the troops were ease of operation, a relatively small number of service units and the lack of refueling facilities.

The emergence of American missile defense systems required the modernization of the missile in relation to new conditions. Work began in 1968. On January 16, 1970, the first test launch of the modernized rocket took place at the Plesetsk test site. Two years later it was adopted.

The modernized RT-2P differed from its predecessor in a more advanced control system, a warhead whose nuclear charge power was increased to 750 kt, and improved operational characteristics. Firing accuracy increased to 1.5 km. The missile was equipped with a complex to overcome missile defense systems. The modernized RT-2Ps, which were supplied to equip missile units in 1974 and previously released missiles modified to their technical level, remained on combat duty until the mid-90s.

By the end of the 60s, conditions began to emerge for achieving nuclear parity between the United States and the Soviet Union. The latter, rapidly increasing the combat potential of its strategic nuclear forces and, above all, its Strategic Missile Forces, could in the coming years catch up with the United States of America in the number of nuclear warheads. Overseas, high-ranking politicians and military personnel were not happy with this prospect.



RS-12, first stage

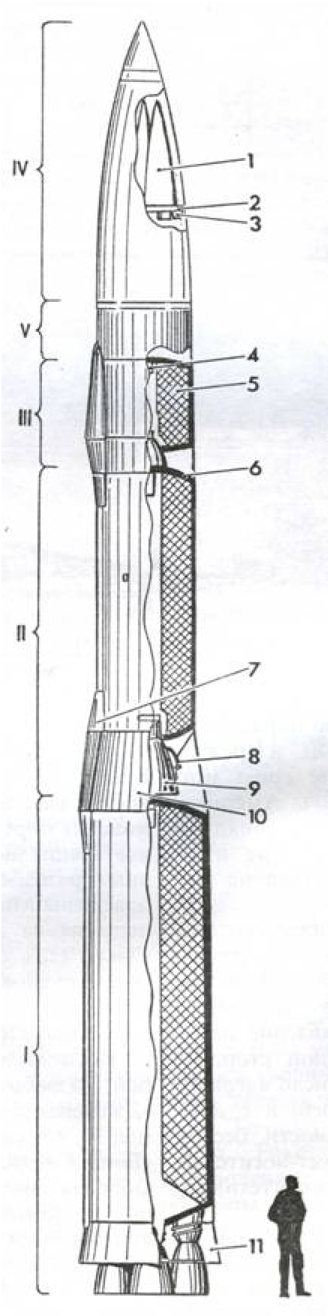
The next round of the missile arms race was associated with the creation of multiple warheads with individually targetable warheads (MRV type MIRV). Their appearance was caused, on the one hand, by the desire to have as large a number of nuclear warheads as possible to destroy targets, and on the other, by the inability to endlessly increase the number of launch vehicles for a number of economic and technical reasons.

The higher level of development of science and technology at that time allowed the Americans to be the first to begin work on the creation of MIRVs. Initially, dispersive type warheads were developed in a special research center. But they were only suitable for hitting area targets due to their low pointing accuracy. Such a MIRV was equipped with the Polaris-AZT SLBM. The introduction of powerful on-board computers made it possible to increase the accuracy of guidance. At the end of the 60s, specialists from the research center completed the development of individual target MIRVs Mk12 and Mk17. Their successful tests at the White Sands Army Test Site (where all American nuclear warheads were tested) confirmed the possibility of their use on ballistic missiles.

The carrier of the Mk12, the design of which was developed by representatives of the General Electric company, was the Minuteman-3 ICBM, the design of which Boeing began at the end of 1966. Possessing high shooting accuracy, according to the plan of American strategists, it was supposed to become a “thunderstorm of Soviet missiles.” The previous model was taken as a basis. No significant modifications were required, and in August 1968 the new missile was transferred to the Western Missile Range. There, according to the flight design test program for the period from 1968 to 1970, 25 launches were carried out, of which only six were considered unsuccessful. After the completion of this series, six more demonstration launches were carried out for high authorities and ever-doubting politicians. All of them were successful. But they were not the last in the history of this ICBM. During its long service, 201 launches were carried out both for testing and training purposes. The missile showed high reliability. Only 14 of them ended unsuccessfully (7% of the total).

The Minuteman-3 ICBM structurally consists of three sequentially located solid propellant rocket engines and a MIRV with a fairing attached to the third stage. The engines of the first and second stages are M-55A1 and SR-19, inherited from their predecessors. The SR-73 solid propellant rocket motor was designed by United Technologies specifically for the third stage of this rocket. It has a bonded solid propellant charge and one fixed nozzle. During its operation, the pitch and yaw angles are controlled by liquid injection into the supercritical part of the nozzle, and the roll control is carried out using an autonomous gas generator system installed on the hull skirt.

The new NS-20 brand control system was developed by the Otonetics division of Rockwell International. It is designed to control flight in the active part of the trajectory; calculating trajectory parameters in accordance with the flight mission recorded in the storage devices of the three-channel digital computer; calculating control commands for the drives of the rocket actuators; managing the warhead breeding program when targeting individual targets; carrying out self-monitoring and monitoring the functioning of on-board and ground systems during combat duty and pre-launch preparation. The main part of the equipment is located in a sealed instrument compartment. GSP gyroblocks are in an untwisted state when on combat duty. The generated heat is removed by a temperature control system. The control system provides shooting accuracy (CAO) of 400 m.



ICBM "Minuteman-3" (USA) 1970

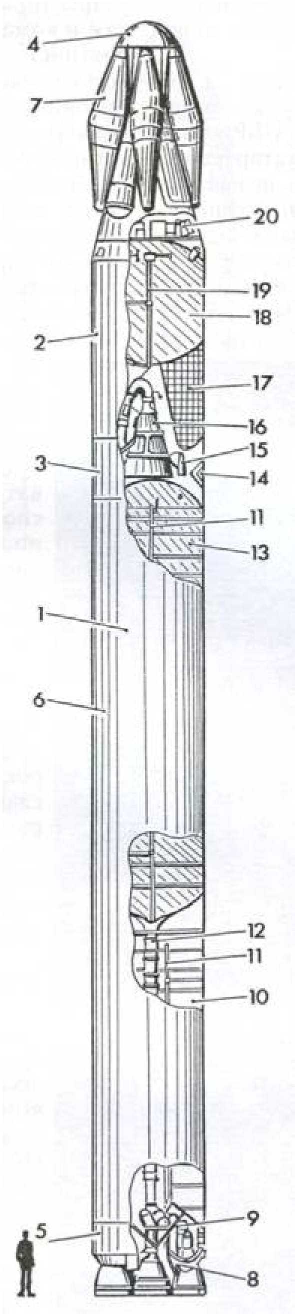
I - first stage; II - second stage; III - third stage; IV - head part; V - connecting compartment; 1 — combat unit; 2 — platform of warheads; 3 — electronic units for automatic combat units; 4 — solid propellant rocket launcher; 5 — charge of solid fuel of the rocket engine; 6 — thermal insulation of the rocket engine; 7 - cable box; 8 — gas injection device into the nozzle; 9 — solid propellant nozzle; 10 — connecting skirt; 11 — tail skirt.

Let’s take a special look at the design of the Mk12 warhead. Structurally, the MIRV consists of a combat compartment and a breeding stage. In addition, a complex of means for overcoming missile defense can be installed, which uses dipole reflectors. The weight of the head part with

At the bottom of the breeding stage there is a propulsion system, which includes an axial thrust engine, 10 orientation and stabilization engines and two fuel tanks. To power the propulsion system, two-component liquid fuel is used. The displacement of components from the tanks is carried out by the pressure of compressed helium, the supply of which is stored in a spherical cylinder. Axial thrust engine thrust - 143 kg. The operating time of the remote control is about 400 seconds. The power of the nuclear charge of each warhead is 330 kt.

In a relatively short time, a group of 550 Minuteman-3 missiles was deployed at four missile bases. The missiles are in the silo in 30-second readiness for launch. The launch was carried out directly from the mine shaft after the first stage solid propellant rocket engine entered operating mode.

All Minuteman-3 missiles have been modernized more than once. The charges of the first and second stage rocket engines were replaced. The characteristics of the control system were improved by taking into account the errors of the command instrument complex and the development of new algorithms. As a result, the firing accuracy (CA) was 210 m. In 1971, a program began to improve the security of silo launchers. It included strengthening the silo structure, installing a new missile suspension system and a number of other measures. All work was completed in February 1980. The security of the silos was brought to a value of 60–70 kg/cm².



ICBM RS-20A with MIRV (USSR) 1975

1 - first stage; 2 - second stage; 3 — connecting compartment; 4 — head fairing; 5 — tail section; 6 —carrying tank of the first stage; 7 — combat unit; 8 — first stage propulsion system; 9 — frame for mounting the propulsion system; 10 — first stage fuel tank; 11 — first stage ASG lines; 12 — oxidizer supply pipeline; 13 — first stage oxidizer tank; 14 — power element of the connecting compartment; 15 — steering rocket engine; 16 — propulsion system of the second stage; 17 — second stage fuel tank; 18 — second stage oxidizer tank; 19 — ASG line; 20 — control system equipment.

one on 300 Minuteman-3 missiles. The charge power of each warhead was increased to 0.5 Mt. True, the area for spreading the blocks and the maximum flight range have decreased somewhat. Overall, this ICBM is reliable and capable of hitting targets throughout the former Soviet Union. Experts believe that it will be on combat duty until the beginning of the next millennium.

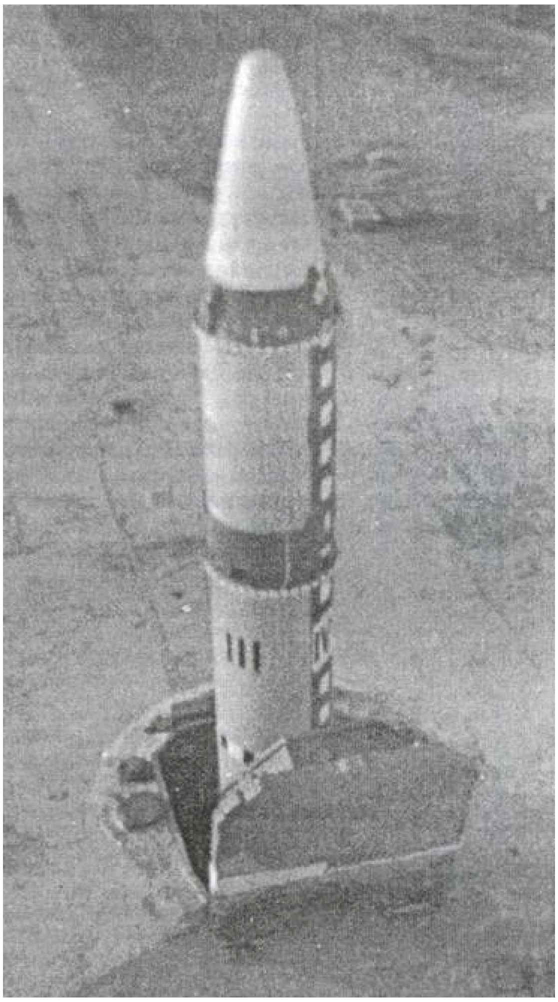
The appearance of missiles with MIRVs in the US strategic nuclear forces sharply worsened the situation of the USSR. Soviet ICBMs immediately fell into the category of obsolete, since they could not solve a number of newly emerging problems, and most importantly, the likelihood of delivering an effective retaliatory strike was significantly reduced. There was no doubt that the warheads of the Minuteman-3 missiles, in the event of a nuclear war, would strike silo launchers and command posts of the Strategic Missile Forces. And the likelihood of such a war at that time was very high. In addition, in the second half of the 60s, work in the field of missile defense intensified in the United States.

The problem could not be resolved simply by creating a new ICBM. It was necessary to improve the combat control system for missile weapons, increase the protection of command posts and launchers, and also solve a number of related problems. After a detailed study by specialists of options for the development of the Strategic Missile Forces and a report of the research results to the state leadership, it was decided to develop heavy and medium missiles capable of carrying a significant payload and ensuring the achievement of parity in the field of nuclear weapons. But this meant that the Soviet Union was being drawn into a new round of the arms race, and in the most dangerous and expensive area.

The Dnepropetrovsk Design Bureau, which after the death of M. Yangel was headed by Academician V.F. Utkin, was tasked with creating a heavy rocket. There, in parallel, development work began on a rocket with a lower launch mass.

The heavy ICBM RS-20A took off on its first test flight on February 21, 1973 from the Baikonur test site. Due to the complexity of the technical problems being solved, the development of the entire complex dragged on for two and a half years. At the end of 1975, on December 30, the new DBK with this missile was put on combat duty. Having inherited all the best from the R-36, the new ICBM has become the most powerful missile in its class.

The rocket was made according to the "tandem" design with a sequential separation of stages and structurally included the first, second and combat stages. The supporting structure fuel tanks were made of metal alloys. The separation of the stages was ensured by the actuation of explosive bolts.



RS-20A ICBM with monoblock warhead

The first-stage propulsion rocket engine combined four autonomous propulsion blocks into a single design. Control forces in flight were created by deflecting the nozzle blocks.

The propulsion system of the second stage consisted of a propulsion rocket engine, made in a closed circuit, and a four-chamber steering engine, made in an open circuit. All liquid-propellant rocket engines operated on high-boiling liquid fuel components that ignited on contact.

An autonomous inertial control system was installed on the rocket, the operation of which was ensured by an on-board digital computer complex. To increase the reliability of the BTsVK, all its main elements had redundancy. During combat duty, the on-board computer ensured the exchange of information with ground devices. The most important parameters of the technical condition of the rocket were controlled by the control system. The use of BTsVK made it possible to achieve high shooting accuracy. The CEP of the impact points of the warheads was 430 m.

overcoming anti-missile defense systems.

ICBM RS-20B (USSR) 1980

The RS-20A missile, placed in a transport and launch container, was installed in an OS-type silo launcher in a fueled state and could be on combat duty for a long time. Preparation for launch and launch of the rocket were carried out automatically after the control system received a launch command. To exclude unauthorized use of nuclear missile weapons, the control system accepted for execution only commands defined by a code key. The implementation of such an algorithm was made possible by the introduction of a new centralized combat control system at all command posts of the Strategic Missile Forces.

This missile was in service until the mid-80s, until it was replaced by the RS-20B. Its appearance, like all its contemporaries in the Strategic Missile Forces, is due to the development by the Americans of neutron ammunition, new achievements in the field of electronics and mechanical engineering, and increasing requirements for the combat and operational characteristics of strategic missile systems.

The RS-20B ICBM differed from its predecessor in a more advanced control system and a combat stage modified to the level of modern requirements. Due to powerful energy, the number of warheads on the MIRV was increased to 10.

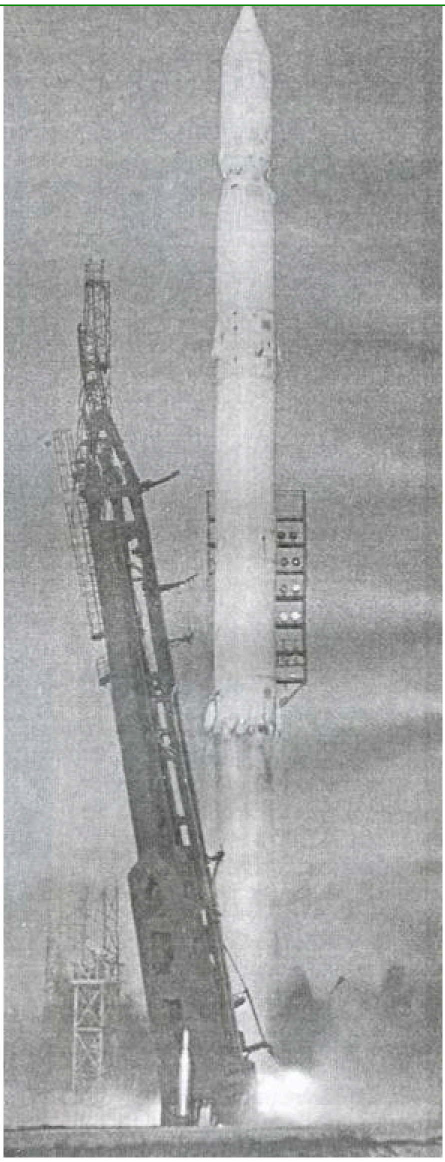
The combat equipment itself has also changed. Since shooting accuracy has increased, it has become possible to reduce the power of nuclear charges. As a result, the flight range of the missile with a monoblock warhead was increased to 16,000 km.

R-36 missiles have also found use for peaceful purposes. On their basis, a launch vehicle was created to launch into orbit spacecraft of the "Cosmos" series for various purposes.

Another brainchild of Utkin Design Bureau was the PC-16A ICBM. Although it was the first to enter testing (the launch at Baikonur took place on December 26, 1972), it was accepted into service on the same day along with the RS-20 and PC-18, the story of which is yet to come.

The RS-16A rocket is a two-stage rocket with liquid fuel engines, designed in a "tandem" configuration with sequential separation of stages in flight. The rocket body has a cylindrical shape with a conical head. Fuel tanks of supporting structure.

RS-20V ICBM in flight

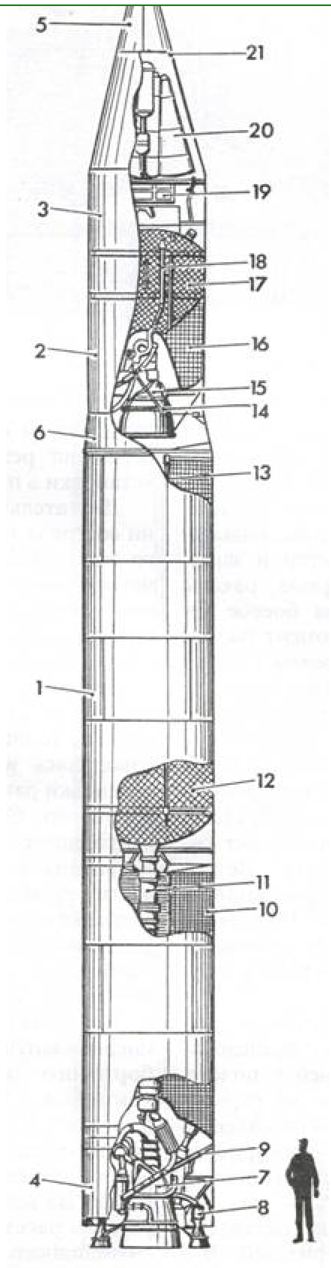


Space rocket complex "Cyclone" based on RS-20B

The propulsion system of the first stage consisted of a propulsion liquid rocket engine, made in a closed circuit, and a steering four-chamber liquid-propellant rocket engine, made in an open circuit with rotary combustion chambers.

At the second stage, one sustaining single-chamber liquid-propellant rocket engine was installed, designed in a closed circuit, with a portion of the exhaust gas being blown into the supercritical part of the nozzle to create control forces in flight. All rocket engines operate on high-boiling, self-igniting oxidizer and fuel on contact. To ensure stable engine operation, the fuel tanks were pressurized with nitrogen. The rocket was refueled after installation in the launch silo.

An autonomous inertial control system with an on-board computer complex was installed on the rocket. It provided control of all missile systems during combat duty, pre-launch preparation and launch. The established algorithms for the functioning of the control system in flight made it possible to ensure a firing accuracy of no more than 470 m. The RS-16A missile was equipped with a multiple warhead with four individually targeted warheads, each of which contained a nuclear charge with a power of 750 kt.



ICBM PC-16A (USSR) 1975

1 — first stage, 2 — second stage, 3 — instrument compartment, 4 — tail section, 5 — fairing of the head part, 6 — connecting compartment, 7 — first stage propulsion system, 8 — steering liquid-propellant rocket engine, 9 — propulsion system mounting frame, 10 — first stage fuel tank, 11 — oxidizer supply pipeline, 12 — first stage oxidizer tank, 13 — ASG line, 14 — second stage propulsion system mounting frame, 15 — second stage propulsion system, 16 — second stage fuel tank, 17 — second stage oxidizer tank, 18 — oxidizer tank pressurization line, 19 — electronic control units, 20 — combat unit, 21 — head fairing mounting hinge.

The great advantage of the new combat missile system was that the missiles were installed in silo launchers previously built for first and second generation ballistic missiles. It was necessary to carry out the necessary amount of work to improve some silo systems and it was possible to load new missiles. This resulted in significant financial savings.

On October 25, 1977, the first launch of the modernized missile, designated RS-16B, took place. Flight tests were carried out at Baikonur until September 15, 1979. On December 17, 1980, the DBK with a modernized missile was put into service.

The new missile differed from its predecessor in an improved control system (the accuracy of delivery of warheads increased to 350 m) and a combat stage. The multiple warhead installed on the missile has also undergone modernization. The missile's combat capabilities have increased by 1.5 times, the reliability of many systems and the security of the entire DBK have increased. The first RS-16B missiles were put on combat duty in 1980, and at the time of the signing of the START-1 Treaty, the Strategic Missile Forces had 47 missiles of this type in service.

ICBM RS-16A assembled without warhead (outside the launch container)

The third missile that entered service during this period was the PC-18, developed in the design bureau of Academician V. Chelomey. This missile was supposed to harmoniously complement the strategic weapons system being created. Her first flight took place on April 9, 1973. Flight design tests took place at the Baikonur test site until the summer of 1975, after which the State Commission considered it possible to adopt the DBK for service.

The PC-18 rocket is a two-stage rocket, designed in a "tandem" configuration with sequential separation of stages in flight. Structurally, it consisted of the first and second stages, connecting compartments, an instrument compartment and an instrumentation unit with a split warhead.

The first and second stages made up the so-called accelerator block. All fuel tanks are of a supporting structure. The first stage propulsion system had four propulsion liquid rocket engines with rotary nozzles. One of the rocket engines was used to maintain the operating mode of the propulsion system in flight.

The propulsion system of the second stage consisted of a propulsion rocket engine and a steering liquid engine, which had four rotary nozzles. To ensure stable operation of the rocket engines of the accelerator block in flight, pressurization of the fuel tanks was provided.

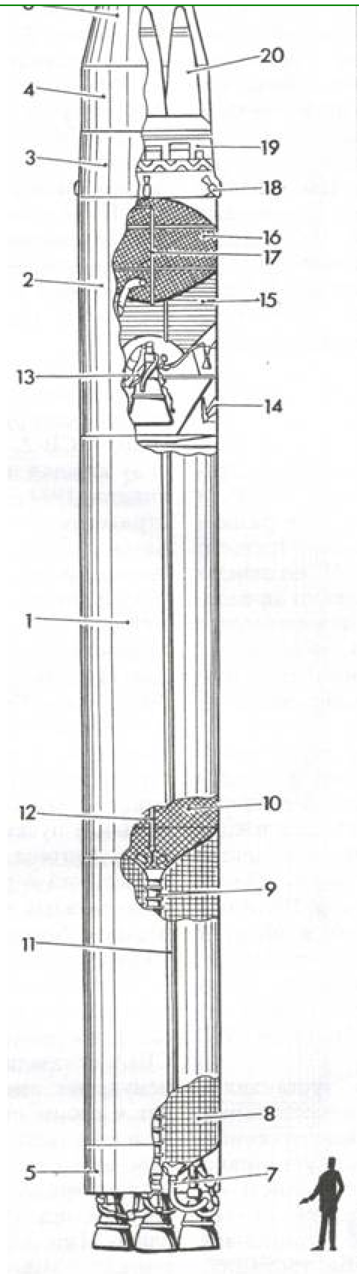
All rocket engines operated on self-igniting stable rocket fuel components. Refueling was carried out at the factory after the missile was installed in the transport and launch container. However, the design of the pneumatic-hydraulic system of the rocket and the TPK made it possible, if necessary, to carry out operations to drain and subsequently refuel the rocket fuel components. The pressure in all rocket tanks was continuously monitored by a special system.

An autonomous inertial control system based on an on-board digital computer complex was installed on the rocket. While on combat duty, the control system, together with the ground-based central control system, monitored the on-board systems of the missile and adjacent systems of the launcher. The missile was launched into all operational and combat modes remotely from the DBK command post. The high characteristics of the control system were confirmed during test launches. The firing accuracy (CA) was 350 m. The RS-18 carried a MIRV with six individually targetable warheads with a nuclear charge of 550 kt and could hit highly protected enemy target targets covered by missile defense systems.

The missile was "ampulized" in a transport and launch container, which was placed in silo launchers with a high degree of protection specially created for this missile system.

The DBK with the PC-18 ICBM was a significant step forward even in comparison with the missile system with the RS-16A missile adopted at the same time. But as it turned out, during operation it was not without its shortcomings. In addition, during combat training launches of missiles put on combat duty, a defect in the liquid propellant engine of one of the stages was revealed. Things took a serious turn. As always, there were some "switchmen" to blame. Colonel General M. G. Grigoriev was removed from the post of First Deputy Commander-in-Chief of the Strategic Missile Forces, whose only fault was that he was the chairman of the State Commission for testing the missile system with the RS-18 missile.

These problems accelerated the adoption of a modernized missile under the same designation RS-18 with improved tactical and technical characteristics, flight tests of which were carried out from October 26, 1977. In November 1979, the new DBK was officially adopted to replace its predecessor.



ICBM RS-18 (USSR) 1975

1 — first stage body; 2 — second stage body; 3 — sealed instrument compartment; 4 - combat stage; 5 — tail section of the first stage; 6 — fairing of the head part; 7 — first stage propulsion system; 8 — first stage fuel tank; 9 — oxidizer supply pipeline; 10 — first stage oxidizer tank; 11 - cable box; 12 - ASG line; 13 — propulsion system of the second stage; 14 — power element of the connecting compartment housing; 15 — second stage fuel tank; 16 — second stage oxidizer tank; 17 - ASG line; 18 — solid propellant braking motor; 19 — control system devices; 20 - combat unit.

On the improved rocket, defects in the rocket engines of the accelerator block were eliminated, while their reliability was increased, the characteristics of the control system were improved, a new instrumentation unit was installed, which increased the flight range to 10,000 km, and the efficiency of combat equipment was increased.

The command post of the missile system has undergone significant modifications. A number of systems were replaced with more advanced and reliable ones. We increased the degree of protection from the damaging factors of a nuclear explosion. The changes made significantly simplified the operation of the entire combat missile system, which was immediately noted in reviews from military units.

From the second half of the 70s, the Soviet Union began to experience a lack of financial resources for the harmonious development of the country's economy, which was caused not least by large expenditures on armaments. Under these conditions, the modernization of all three missile systems was carried out with the maximum degree of saving financial and material resources. Improved missiles were installed in place of old ones, and modernization in most cases was carried out by bringing existing missiles to new standards.

The efforts made in the 70s to further improve and develop missile weapons in our country played an important role in achieving strategic parity between the USSR and the USA. The adoption and deployment of third-generation missile systems equipped with individually targeted MIRVs and means of penetrating missile defenses has made it possible to achieve an approximate equality in the number of nuclear warheads on strategic carriers (excluding strategic bombers) of both states.

During these years, the development of ICBMs, like SLBMs, began to be influenced by a new factor - the process of limiting strategic weapons. On May 26, 1972, during a summit meeting in Moscow, the Interim Agreement between the Soviet Union and the United States of

The interim agreement established quantitative and qualitative restrictions on fixed ICBM launchers, SLBM launchers and ballistic missile submarines. The construction of additional stationary ground-based ICBM launchers was prohibited, which fixed their quantitative level as of July 1, 1972 for each of the parties.

Modernization of strategic missiles and launchers was permitted on the condition that the launchers of ground-based light ICBMs, as well as ballistic missiles deployed before 1964, would not be converted into launchers for heavy missiles.

In 1974–1976, in accordance with the Protocol on procedures governing the replacement, dismantling and destruction of strategic offensive weapons, the Strategic Missile Forces removed from combat duty and eliminated 210 R-16U and R-9A ICBM launchers with equipment and structures for launch positions. The United States did not need to carry out such work.

On June 19, 1979, a new treaty on the limitation of strategic arms was signed in Vienna between the USSR and the USA, which was called the SALT-2 Treaty. If it came into force, each of the parties had to limit the level of strategic carriers to 2250 units from January 1, 1981. Carriers equipped with individually targeted MIRVs were subject to restrictions. In the established total limit, they should not exceed 1320 units. Of this number, the limit for ICBM launchers was set at 820 units. In addition, strict restrictions were imposed on the modernization of stationary launchers of strategic intercontinental missiles - the creation of mobile launchers of such missiles was prohibited. Only one new type of light ICBM with a number of warheads not exceeding 10 was allowed to be flight tested and deployed.

Despite the fact that the SALT II Treaty fairly and balancedly took into account the interests of both sides, the US administration refused to ratify it. And no wonder: Americans are thoughtful about their interests. By that time, most of their nuclear warheads were on SLBMs, and in order to fit within the established limits on carriers, 336 missiles would have to be eliminated. They were to be either the ground-based Minutemen-3 or the sea-based Poseidons, recently adopted into service with modern SSBNs. At that time, testing of the new Ohio SSBN with the Trident 1 missile had just finished, and the interests of the American military-industrial complex could have been seriously damaged. In a word, from the financial side, the government and the US military-industrial complex were not satisfied with this Treaty. However, there were other reasons to refuse its ratification. But although the SALT II Treaty never came into force, the parties still adhered to some restrictions.

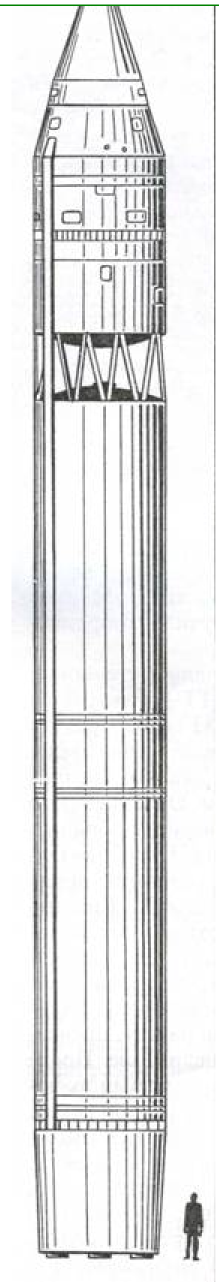
During that period, another state began to arm itself with intercontinental ballistic missiles. At the end of the 70s, the Chinese took up the creation of ICBMs. They needed such a missile to bolster their claims to a leading role in the Asian region and the Pacific Ocean. Possessing such weapons could also threaten the United States.

Flight testing of the Dun-3 missile was carried out over a limited range - China did not have prepared test routes of significant length. The first such launch was carried out from the Shuangengzi test site at a range of 800 km. The second launch was carried out from the Wuzhai test site to a range of about 2000 km. The tests were clearly dragging on. Only in 1983, the Dong-3 ICBM (Chinese designation - Dongfeng-5) was adopted by the nuclear forces of the People's Liberation Army of China.

In terms of technical level, it corresponded to Soviet and American ICBMs of the early 60s. The two-stage rocket with sequential separation of stages had an all-metal body. The steps were connected to each other through a transition compartment of the truss structure. Due to the low energy characteristics of the engines, the designers had to increase the fuel supply in order to achieve the specified flight range. The maximum diameter of the missile was 3.35 m, which is still a record for an ICBM.

The inertial control system, traditional for Chinese missiles, ensured a firing accuracy of 3 km. Dun-3 carried a monoblock nuclear warhead with a capacity of 2 Mt.

The survivability of the complex as a whole remained low. Despite the fact that the ICBM was placed in a silo launcher, its protection did not exceed 10 kg/cm² (in terms of pressure in the shock wave front). For the 80s this was clearly not enough. The Chinese missile lagged significantly behind American and Soviet missile technology in all important combat indicators.



ICBM "Dong-3" (China) 1983

Equipping combat units with this missile was carried out slowly. In addition, a launch vehicle was created on its basis to launch spacecraft into near-Earth orbits, which could not but affect the rate of production of combat intercontinental missiles.

In the early 90s, the Chinese modernized the Dong-3. A significant jump in the level of the economy made it possible to raise the level of rocket science. Dong-ZM became the first Chinese ICBM with MIRV. It was equipped with 4–5 individually targeted warheads with a capacity of 350 kt each. The characteristics of the missile control system were improved, which immediately affected the firing accuracy (the COE was 1.5 km). But even after modernization, this missile cannot be considered modern in comparison with foreign analogues.

Let's go back to the USA in the seventies. In 1972, a special government commission studied the prospects for the development of US strategic nuclear forces until the end of the 20th century. Based on the results of its work, President Nixon's administration issued an order to develop a promising ICBM capable of carrying MIRVs with 10 individually targetable warheads. The program received the MX cipher. The advanced research phase lasted six years. During this time, one and a half dozen rocket projects with a launch weight from 27 to 143 tons, presented by various companies, were studied. As a result, the choice fell on the project of a three-stage rocket with a mass of about 90 tons, capable of being placed in the silos of Minuteman missiles.

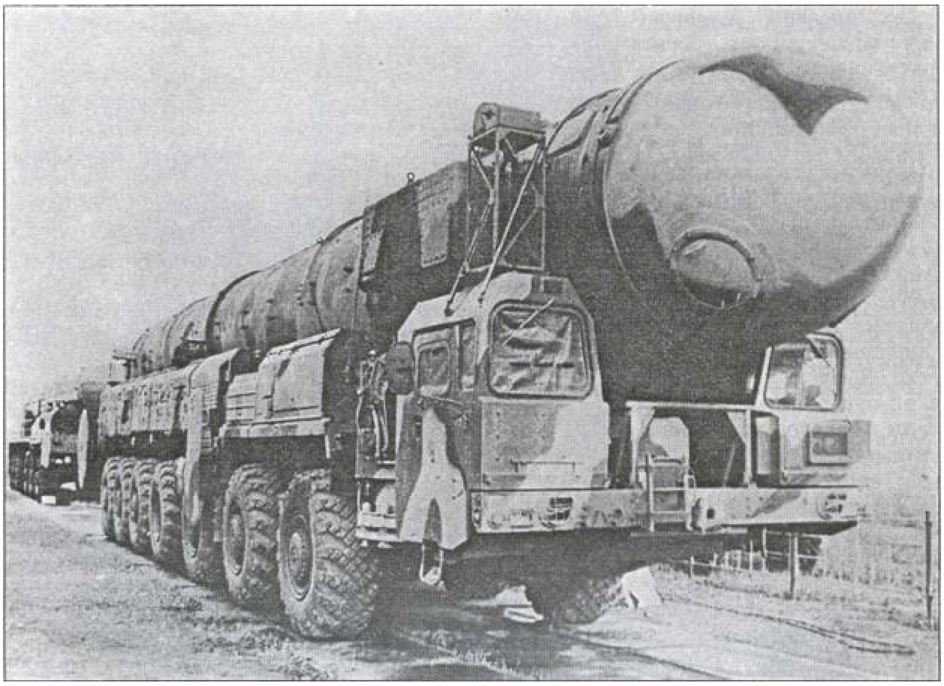
In the period from 1976 to 1979, intensive experimental work was carried out both on the design of the rocket and on its possible basing. In June 1979, President Carter decided to undertake full-scale development of a new ICBM. The parent company was Martin Marietta, which was entrusted with the coordination of all work.

In April 1982, bench fire tests of the solid propellant rocket stages began, and a year later - on June 17, 1983 - the rocket set off on its first test flight to a range of 7600 km. It was considered quite successful. Simultaneously with flight tests, basing options were being studied. Initially, three options were considered: mine, mobile and air. For example, it was planned to create a special carrier aircraft, which was supposed to carry out combat duty by loitering in designated areas and, upon a signal, drop a missile, having previously aimed it. After separation from the carrier, the first stage propulsion engine had to be turned on. But this, as well as a number of other possible options, remained on paper. The American military really wanted to get the latest missile with a high degree of survivability. By that time, the main way had become to create mobile missile systems, the location of the launchers of which could change in space, which created difficulties for delivering a targeted nuclear strike on them. But the principle of saving money prevailed. Since the tempting air option was extremely expensive, and the Americans did not

In 1986, the LGM-118A missile, called the Peacekeeper, entered service (in Russia it is better known as the MX). When creating it, the developers used all the latest innovations in the field of materials science, electronics and instrument engineering. Much attention was paid to reducing the mass of structures and individual elements of the rocket.

MX includes three sustainer stages and a MIRV. They all have the same design and consist of a housing, a solid fuel charge, a nozzle block and a thrust vector control system. The first stage solid propellant rocket motor was created by Thiokol. Its body is wound from Kevlar-49 fibers, which have high strength and low weight. The front and rear bottoms are made of aluminum alloy. The nozzle block is deflectable with flexible supports.

The second stage solid propellant rocket engine was developed by Aerojet and is structurally different from the Thiokol engine in the nozzle block. The high expansion deflectable nozzle has a telescopic nozzle for increased length. It is pushed into the working position using a gas generator device after the rocket engine of the previous stage is separated. To create control forces for rotation at the stage of operation of the first and second stages, a special system is installed, consisting of a gas generator and a control valve that redistributes the gas flow between two obliquely cut nozzles. The Hercules third-stage solid propellant rocket engine differs from its predecessors in the absence of a thrust cut-off system, and its nozzle has two telescopic nozzles. Dual-mix fuel charges are poured into finished rocket engine housings.



SPU ICBM RS-12M

The steps are connected to each other using adapters made of aluminum. The entire rocket body is covered on the outside with a protective coating that protects it from heating by hot gases during launch and from the damaging factors of a nuclear explosion.

The inertial control system of a missile with a Meka-type on-board central control system is located in the compartment of the MIRV propulsion system, which made it possible to save the overall length of the ICBM. It provides flight control during the active part of the trajectory, at the stage of disengagement of warheads, and is also used while the missile is on combat duty. The high quality of GPS devices, taking into account errors and the use of new algorithms ensured a shooting accuracy of about 100 m. To create the necessary temperature conditions, the in-flight control system is cooled with freon from a special tank. Pitch and yaw angles are controlled by deflectable nozzles.

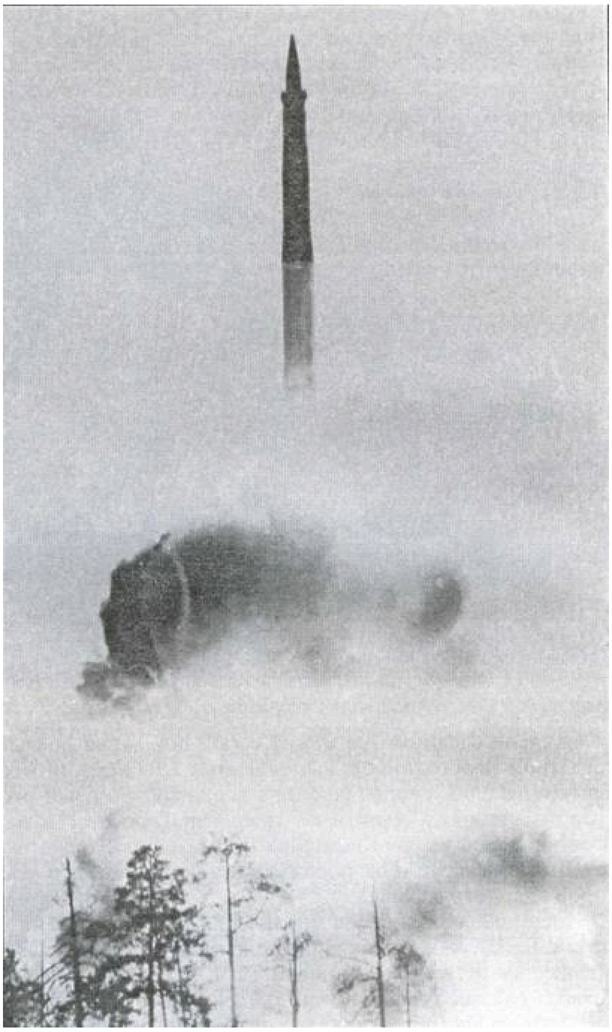
The MX ICBM is equipped with a Mk21 split warhead, consisting of a warhead compartment covered by a fairing and a propulsion unit compartment. The first compartment has a maximum capacity of 12 warheads, similar to the Minuteman-ZU missile warhead. Currently, it houses 10 individually targeted warheads with a capacity of 600 kt each. Propulsion system with multiple firing liquid rocket engine. It is launched at the stage of operation of the third stage and ensures the disengagement of all combat equipment. A new set of means for overcoming missile defense systems has been developed for the MK21 MIRV, including light and heavy decoys and various jammers.

The rocket is placed in a container from which it is launched. For the first time, the Americans used a "mortar launch" to launch an ICBM from a silo launcher. The solid fuel gas generator, located in the lower part of the container, when triggered, ejects the rocket to a height of 30 m from the level of the silo protective device, after which the first stage propulsion engine is turned on.

According to American experts, the combat effectiveness of the MX missile system is 6–8 times greater than that of the Minuteman-3 system. In 1988, the program to deploy 50 Peacekeeper ICBMs ended. However, the search for ways to increase the survivability of these missiles has not been completed. In 1989, a railway mobile missile system entered testing. It consisted of a launch car, a combat control car equipped with the necessary control and communication equipment, as well as other cars that ensured the functioning of the entire complex. This DBK was tested at the training ground of the Ministry of Railways until mid-1991. Upon completion, it was planned to deploy 25 trains with 2 launchers each. In peacetime, they were all supposed to be at a point of permanent deployment. With the transfer to the highest levels of combat readiness, the US strategic nuclear forces command planned to disperse all trains throughout the railway network of the United States of America. But the signing of the START Limitation and Reduction Treaty in July 1991 changed these plans. The railway missile system never entered service.

In the USSR, in the mid-80s, missile weapons of the Strategic Missile Forces received further development. This was caused by the implementation of the American strategic defense initiative, which provided for the launch into space orbits of nuclear weapons and weapons based on new physical principles, which created an extremely high danger and vulnerability for the strategic nuclear forces of the USSR throughout the territory. To maintain strategic parity, it was decided to create new silo- and railway-based missile systems with RT-23 UTTX missiles, similar in their characteristics to the American MX, and to modernize the RS-20 and PC-12 ballistic missile systems.

The first of them, in 1985, adopted a mobile missile launcher with the RS-12M missile. The accumulated wealth of experience in operating mobile ground-based systems (for operational-tactical missiles and medium-range missiles) allowed Soviet designers to quickly create a



RS-12M ICBM in flight

In 1986, the State Commission adopted a railway missile system with an RT-23UTTKh ICBM, and two years later, the RT-23UTTKh, located in silos previously used for RS-18 missiles, entered service with the Strategic Missile Forces. After the collapse of the USSR, 46 of the latest missiles ended up on the territory of Ukraine and are currently subject to destruction.

All these rockets are three-stage, with solid fuel engines. Their inertial control system ensures high shooting accuracy. The RS-12M ICBM carries a monoblock nuclear warhead with a capacity of 550 kt, and both modifications of the RS-22 carry an individually targeted MIRV with ten warheads.

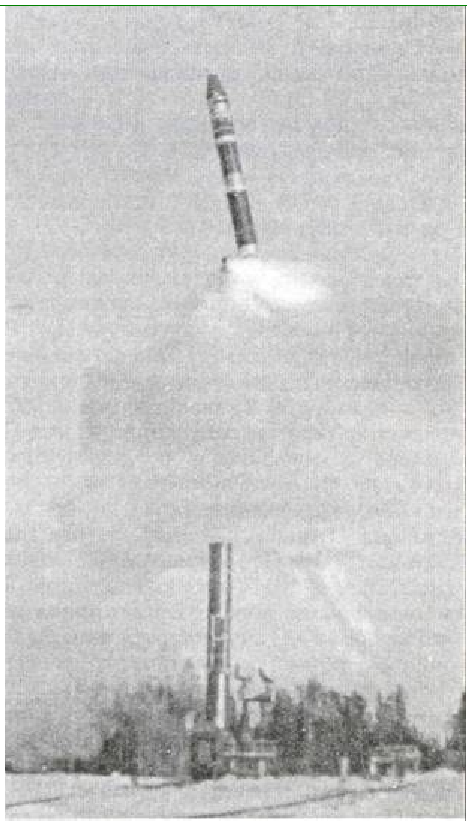
The heavy intercontinental missile RS-20V entered service in 1988. It remains the most powerful rocket in the world and is capable of carrying a payload twice as large as the American MX.

With the signing of the START I Treaty, the development of intercontinental missiles in the United States and the Soviet Union came to a halt. At that time, each country was developing a complex with a small-sized missile to replace outdated third-generation ICBMs.

The American Midgetman program began in April 1983 in accordance with the recommendations of the Scowcroft Commission, appointed by the US President to develop proposals for the development of land-based intercontinental missiles. The developers were given quite stringent requirements: to ensure a flight range of 11,000 km, and reliable destruction of small targets with a monoblock nuclear warhead. In this case, the missile should have a mass of about 15 tons and be suitable for placement in silos and on mobile ground installations. Initially, this program was given the status of the highest national priority and work began in full swing. Very quickly, two versions of a three-stage rocket with a launch mass of 13.6 and 15 tons were developed. After a competitive selection, it was decided to develop a rocket with a larger mass. Fiberglass and composite materials were widely used in its design. At the same time, the development of a mobile protected launcher for this missile was underway.

But with the intensification of work on SDI, there has been a tendency to slow down work on the Midgetman program. At the beginning of 1990, President Reagan gave instructions to curtail work on this complex, which was never brought to full readiness.

Unlike the American one, the Soviet DBK of this type was almost ready for deployment by the time the Treaty was signed. Flight tests of the missile were in full swing and options for its combat use were being developed.



Launch of the RS-22B ICBM

Currently, only China continues to develop ICBMs, seeking to create a missile capable of competing with American and Russian models. Work is underway on a solid-fuel rocket with MIRV. It will have three sustainer stages with solid fuel rocket engines and a launch weight of about 50 tons. The level of development of the electronics industry will make it possible (according to some estimates) to create an inertial control system capable of providing a firing accuracy (CAO) of no more than 800 m. It is assumed that it will be based on the new ICBM will be in silo launchers.

Strategic nuclear systems have long turned into weapons of deterrence, and play more into the hands of politicians than the military. And, if strategic missiles are not completely eliminated, then both Russia and the United States will have to replace physically and morally obsolete ICBMs with new ones. Time will tell what they will be like.

Chapter 4. Launch complexes

Along with the creation of a ballistic missile, the designers had to develop a launch complex capable of providing placement, pre-launch preparation and launch of the missile. Over time, the launch complex became more and more complex, but its main element, the starting device, was not modified often. With the improvement of nuclear weapons, the requirements for launch systems began to have a noticeable impact on the development of missiles.

The first launching device used by the German army during the Second World War was the so-called square launch pad. It could be transported from place to place, as long as the terrain profile was suitable for installing the rocket. Stationary positions with concrete platforms were created and actively used in 1944.

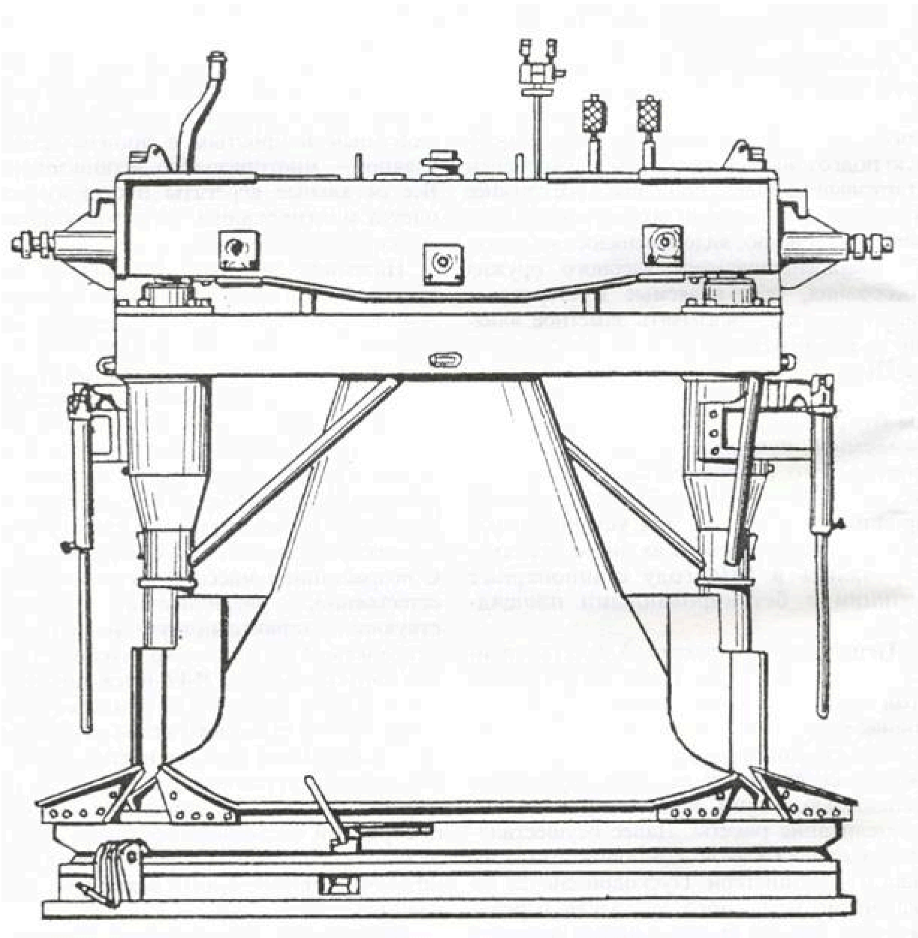
Before launch, the A-4 rocket was installed using a crane on the launch pad in such a way as to ensure that the firing plane coincided with the rocket stabilization plane. After this, the data was entered into the automatic range control. This is how the missile was aimed. Next, the tanks were filled with fuel components from tank trucks. The starting signal to turn on the main engine was transmitted via a cable laid from the location of the launch control point. To ensure the release of the torch of escaping hot gases, the inside of the launch pad had a pyramidal shape. This starting device was reliable and easy to manufacture, and most importantly, reusable. All other units of the launch complex were mounted on a vehicle chassis.

The ground launch device, such as a launch pad, did not disappear along with the A-4 missile. It was used in the launch complexes of the missiles R-1, R-2, R-5M, R-12, R-14 (USSR), Dun-1, Dun-2 (China) and others, practically unchanged, although the composition of the units and systems of missile systems was constantly being improved. In a number of cases, it lost its mobility and was stationary at positions prepared in advance in engineering and geodetic terms (R-14, Dun-1, etc.). With the increase in the mass and size of missiles, naturally, the corresponding characteristics of launch devices also increased. For example, the launch pad for launching the R-12 missile had a width and length of 3.02 m, a height of 3.27 m and a mass of 6.9 tons. The design of the launch pad is determined by the design of the missile and the methods of its guidance and installation. But in any case, it consists of a base, a rotating support, an upper frame, a gas deflector, lifting and rotating mechanisms, an equalizing mechanism and embedded parts.

An interesting design of a ground launch device was used to launch the American Thor MRBM. Since the complex was considered mobile, that is, capable of launching missiles from unprepared positions that met certain conditions, it was necessary to have a launch device with low pressure on the ground. For this purpose, the developers designed a launcher with hinged petal-shaped supports. This design has never been used anywhere else.

The launch pad was used to launch the Soviet R-16 ICBM. At the launch site, two platforms with launching devices, a launch control point, access roads were equipped, and containers for storing rocket fuel components were installed in bunded shelters. The missiles were stored in concrete shelters. If necessary, they were delivered to the launch site on transport and installation carts. After installing the rocket on the launch

The stationary launch complex, created to launch the first Soviet intercontinental missile R-7, had a different design. Its version for launching launch vehicles that put spacecraft into near-Earth orbits was seen by many in television reports from the Baikonur Cosmodrome. Since the rocket had a very large launch mass and considerable dimensions, it was impossible to use a launch pad. A team of designers under the leadership of Barmin developed a new design for the starting device.



Transportable launch pad

The concrete launch position housed a complex of stationary ground equipment, a launch device and other structures, and a command post bunker that ensured the preparation of the rocket for launch. This process lasted several hours. The R-7 rocket was transported from the assembly and testing building, where it was assembled, on a transport and installation unit and, in a horizontal position with unfilled fuel tanks, delivered to the launch position.

The launcher was a metal structure consisting of fixed and moving parts. The fixed part, installed on the canopy of the launch structure, consisted of a two-strand rail ring, a hydraulic drive with a gearbox driving the moving part of the launcher in a circle, thrust rollers, hydraulic jacks with stoppers for fixing the moving part relative to the stationary one with a given azimuthal rotation angle. Azimuthal guidance provided the given direction of the rocket's flight along the course and could be carried out by turning the entire rocket in a horizontal plane using the launcher's rotating mechanism or by introducing the corresponding program into its on-board control system, i.e., without turning the rocket body.

The moving part devices provided installation, fastening, guidance, refueling and maintenance of the rocket. It was installed on a turntable and aligned vertically. On its four bases, four support trusses with supporting booms, with sectors and heads in the upper part and counterweights in the lower part, were hinged. When the support trusses were brought into a vertical position using a hydraulic drive, the sectors formed a closed power ring, on the heads of which the rocket was suspended and held until launch. Its mass kept the ring in a closed state, which, at the moment the rocket left the launcher, opened under the action of counterweights, and the support trusses with supporting booms were retracted from the moving rocket to a safe angle. To avoid the influence of powerful streams of escaping hot gases on the rocket, a deep pit had to be dug under the support ring and equipped with flame arresters. The ICBM was installed at the launch site by a special installer constructed on a railway platform.

With increasing requirements for missile systems, it was necessary to move to new types of launches. The idea arose to “hide” the missile underground, which promised a significant increase in survivability. The Americans were the first to use a silo-type launch complex for their intercontinental missiles.

The Atlas-F ICBM was located on the territory of the missile base, where 12 launch positions were equipped with a launch control point, a missile silo and auxiliary structures at each of them. The starting positions were 10–30 km apart from each other. The shaft design was designed for an excess pressure in the shock wave front of 7 kg/cm². At that time, this was a significant value, since the rocket on the launch pad could withstand a pressure of only 0.2 kg/cm². The shaft had a depth of 53 m and an internal diameter of 15.6 m. On its lower tier there were two tanks for storing liquid oxygen reserves, three tanks with helium for pressurizing the rocket fuel tanks and a tank with liquid nitrogen.

Inside the mine shaft, a launch table was mounted on a movable cradle, which could be raised to ground level using a lift. To carry out maintenance of the rocket, there were several tiers of service platforms. The shaft was closed from above with a double-leaf reinforced concrete roof, which had a thickness of 0.76 m and a mass of 126 tons. Its opening was carried out by a hydraulic drive.

The rocket was stored in a silo with fuel tanks filled. Before the start, it was filled with oxidizer. The control system and components of the rocket were checked, after which the launch pad rose to the surface. All these operations lasted about 13 minutes. On the surface of the earth, if control point were connected to each other by a tunnel laid at a depth of 11.5 m and having a diameter of 2.4 m. Control cables were laid in it. In terms of its security, the launch position of the Atlas ICBM was superior to all launch complexes that existed at that time, and also made it possible to reduce the required time to bring the missile to full combat readiness, since the operations of towing and installing the missile on the launch device were excluded from the launch preparation process.

The designers who created the launch complex for the Titan-1 ICBM, trying to increase its survivability in a nuclear war, took a slightly different path. Nine missiles were placed on one missile base, which included three launch positions measuring 300x300 m. Each of them was equipped with three launch pads with silos, a launch control center, a power station and other structures. Almost all technical and technological equipment was hidden in mines, of which there were three at each launch site. One of them served to accommodate the rocket, the second - to store fuel reserves, and the last - for various equipment.

The mine launcher had a depth of 49 m, a maximum diameter of 13.5 m, which decreased downwards. It was covered by a double-leaf reinforced concrete roof 1 m thick, the mass of which reached 106 tons. To open it, a special hydraulic drive was installed. Inside the shaft, a steel cage with a launch table was suspended on shock absorbers. The rocket was delivered to the launch site via stages and assembled directly in the silo. The launch table was raised and lowered using a hydraulic motor. Before launch, the rocket was raised to ground level.

At a distance of 12 m from the silo there was an auxiliary shaft with a depth of 12 m and a diameter of 12.3 m. Fuel tanks and equipment for refueling the rocket were placed in it, ensuring the filling of the tanks in six minutes. The liquid oxygen supply was stored in a separate double-walled tank.

The third shaft, 21.5 m deep and 13 m in diameter, was installed 15 m from the launcher. It housed systems on four floors that ensured the functioning of the PU units and control and testing equipment. Both auxiliary shafts were protected by a powerful reinforced concrete roof 1.8 m thick.

The launch control center was equipped in an underground two-story room under a powerful reinforced concrete dome, buried 7 m. It carried combat duty and housed combat control equipment, including the Athena computer. At a distance of 180 m from the control point, there were two shafts with a depth of 23 m and a diameter of 9 m for antennas of the radio control system. Before launch, one of them was raised and held on the surface.

The power station was located in a two-story underground room and provided power to consumers at the launch site. All structures were connected to each other by tunnels with a total length of about 900 m. Pipelines and cables for various purposes were laid along them, and people also moved around. The structures had airlock doors, in front of which expansion chambers measuring 4.9x5.3 m were equipped. The security of underground structures was 4–7 kg/cm², and the silos - 20 kg/cm². Such values were record values for that time.

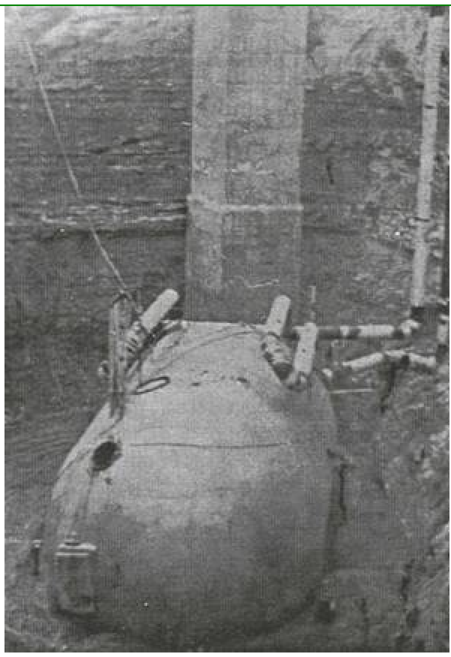
It took 15 minutes to prepare the rocket for launch. During this time, fuel components were refueled, all systems were checked, and the rocket was lifted to the surface. The control antenna extended. Missiles from one launch position could only be launched sequentially, at intervals determined by the guidance cycle of one missile. The complex turned out to be very expensive, which was one of the reasons for the decrease in the total number of Titan-1 ICBMs ordered for deployment at missile bases. The use of control radars reduced its combat value, since even if the missiles were preserved, the destruction of the control antennas did not allow for a targeted launch.

The construction of silo positions with group launches for ballistic missiles became characteristic of Soviet and American missile systems in the first half of the 60s. Moreover, the Americans walked ahead and set the tone. The first silo launchers in the Soviet Union were created for the R-12, R-14 MRBMs and R-16 ICBMs. The development of design documentation for launch positions with silo launchers was carried out by a team of the design bureau headed by V.P. Barmin. Soviet designers took a slightly different path than their American colleagues. The missiles were supposed to be launched directly from the mine shaft. During the design, it was necessary to solve many complex technical problems, such as sinking shafts using a soil freezing system, ensuring the refueling of the rocket with propellant components and high-pressure gases using remote control, etc. In June 1959, experimental silos began to be hastily constructed at the Kapustin Yar test site for R-12 missiles, and despite the difficult hydrogeological conditions in this area, the work of the first stage was completed in a short time. Three months after the start of construction - on August 31, 1959 - the first launch was made.

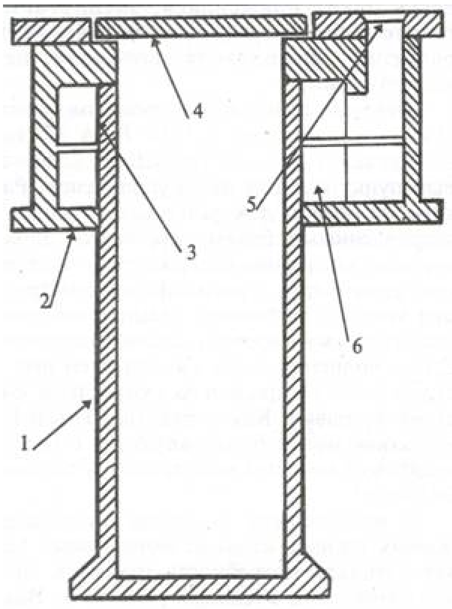
In 1963, the construction and deployment of medium-range ballistic missile systems began in the western regions of the USSR. For R-12U missiles, four silos were built at one position at the corners of a rectangle with dimensions of 80x70 m, and for the R-14U IRBM, three launch silos were equipped at the corners of a right triangle with legs of 80 and 70 m. At each position there was a protected launch control point. The missiles were loaded into launch silos using specially designed installers and stored with empty fuel tanks. Before the launch, pre-launch preparations were carried out, lasting about 2 hours. Despite the fact that the survivability of the missiles has increased, the operational and combat characteristics of these missile systems have increased slightly.

Mine positions with group launches were also created for the R-9A ICBM. At this position there were three silos, a command post and a radio control post. Missiles on combat duty were kept with fuel tanks filled. The supply of liquid oxygen was contained in underground tanks, the original design of which made it possible to store it for a long time with minimal losses. A high-speed filling system was used to fill the tanks with oxidizer before the launch. Like the Titan-1 rockets, the "nines" could be launched from one launch position alternately within 30 minutes.

With the increasing accuracy of intercontinental missile warheads, a need arose to change the method of placing launchers. Indeed, with the existing method of basing ICBMs, the side that was subjected to a surprise nuclear attack risked losing several of its missiles from one enemy nuclear unit placed on a missile that had a higher operational readiness and a flight time shorter than that needed by the side that was attacked in order to strike back. Under these conditions, it was decided to place the launchers in such a way as to ensure that two possible targets would not be hit by one nuclear weapon, that is, to create the so-called PU OS (separate launch). Of course, without the introduction of the latest technologies, the transition to a new system would be difficult.

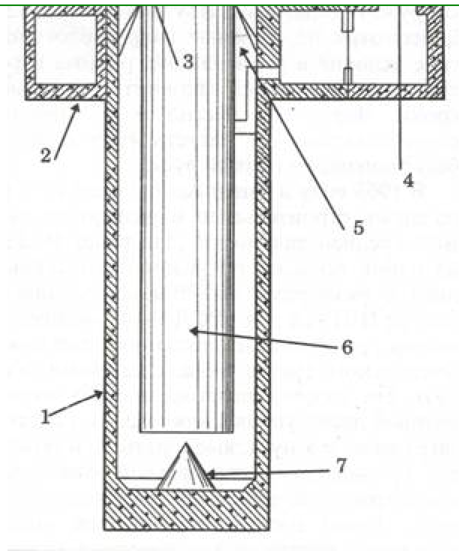


Construction of the Minuteman ballistic missile launch control center



Section of the silo launcher of the Minuteman-2 ICBM

1-"trunk" of the shaft structure; 2-protective shaft head; 3-upper tier of the head; 4- protective cover of the shaft; 5-entry hatch; 6- lower tier of the head



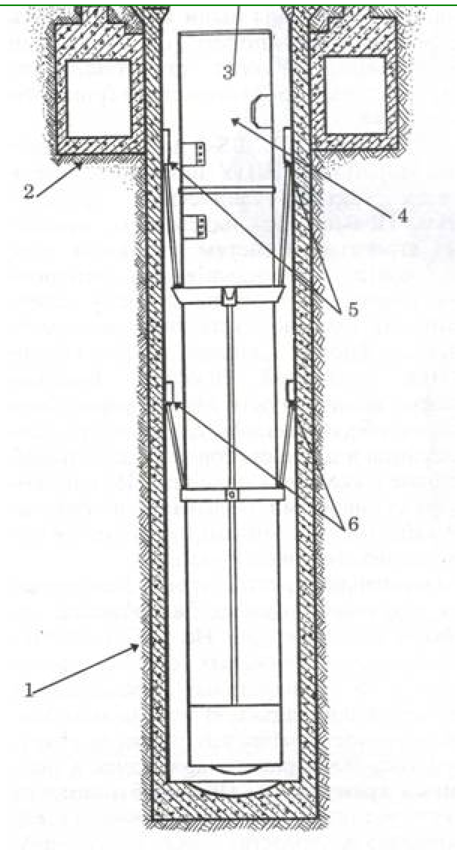
Section of the silo launcher of the ICBM UR-100

1 — "trunk" of the shaft structure; 2 — protective head of the shaft; 3 — protective cover of the shaft; 4 — entrance hatch; 5 — TPK suspension elements; 6 — TPK with a missile; 7 - gas ejector

The Americans, who seized world leadership in the field of electronics in the early 60s, were the first to create an OS silo for the Minuteman-1 ICBM. For ease of control, a squad system was adopted, in which there were 10 automated launchers per launch control center. The detachment's command post, equipped with automated combat command and control systems, was located in an underground protected structure and was connected by cable communication and power supply lines buried in the ground with missile silos located 8-20 km away.

The missile silos were spaced 10–15 km apart. The missile was placed in a closed silo structure, which had a protection of 21 kg/cm² and allowed for maintenance of the missile's onboard systems. The launch was carried out by starting the first stage propulsion engine directly in the mine shaft. To prevent the rocket from burning, its outer surface was coated with heat-protective paint. The entire starting position was covered by barriers and automated security systems.

Subsequently, when replacing the missiles with Minuteman-2(3), some design changes were made. To remove excess heat from the rocket control system, a thermostatting system was installed. Beginning in 1971, work was carried out for 10 years under the VGS program, which provided for increasing the security of all 1000 silos to 60–70 kg/cm². The design of the shaft underwent significant modernization, a new shock absorption system was installed, and a number of technical measures were implemented to reduce the degree of exposure to the electromagnetic pulse and penetrating radiation on the rocket.



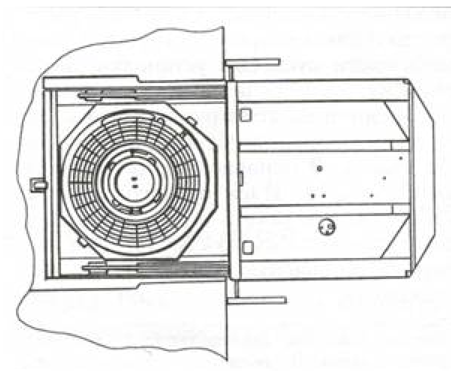
Section of the silo launcher of the RS-16A ICBM

1 — "trunk" of the shaft structure; 2 — protective head of the shaft; 3 — protective cover of the shaft; 4 - TPK with a rocket; 5 — elements of the upper shock-absorbing belt; 6 — elements of the lower shock-absorbing belt

A new launch complex was also created for the Titan-2 ICBM. One missile base included 18 silo launchers, dispersed from each other at a distance of 10–20 km. They were located around the supply center and command post. The missile base occupied an area of 15–16 thousand km 2. The launch position had dimensions of 180›‹80 m. It was equipped with a launch silo and a launch control point. The silo had a depth of 47 m, a maximum internal diameter of 16 m and a two-layer "glass in a glass" type structure (outer layer - steel, inner layer - concrete). The thickness of the structures at the top of the shaft was significantly greater than in the lower part. To remove hot gases flowing from the combustion chambers of the first-stage liquid-propellant rocket engine during rocket launch, two gas exhaust channels were equipped that had access to the surface. The shaft was closed from above with a sliding roof weighing about 680 tons. The rocket was installed on a platform suspended on four spring shock absorbers.

A three-story launch control center was placed under a powerful concrete cap deep in the ground at a distance of 75 m from the silo launcher. On the top floor there were rooms for personnel rest and a dining room. Combat control equipment was installed on the second floor and operator positions were located. The starting position was surrounded by a chain mail fence and equipped with an automated security system with remote control. The security of the silo and launch control point reached 21 kg/cm².

In the second half of the 60s, the Soviet Union also began building OS-type mine positions. All missile systems of the second and third generations had launchers of this type. They, of course, were somewhat different from each other in design, which primarily depended on the chosen starting method. Basically, two starting methods were used. The idea of the first was that the rocket is ejected from the silo by a special pressure accumulator to a safe height, after which the first stage engines are started (the "mortar launch" method). In the second method, the rocket is launched using its propulsion engines directly from the transport and launch container. Both of these methods made it possible to reuse the launcher after carrying out the necessary repair and restoration work.



Silo launcher UR-100 with an open protective roof

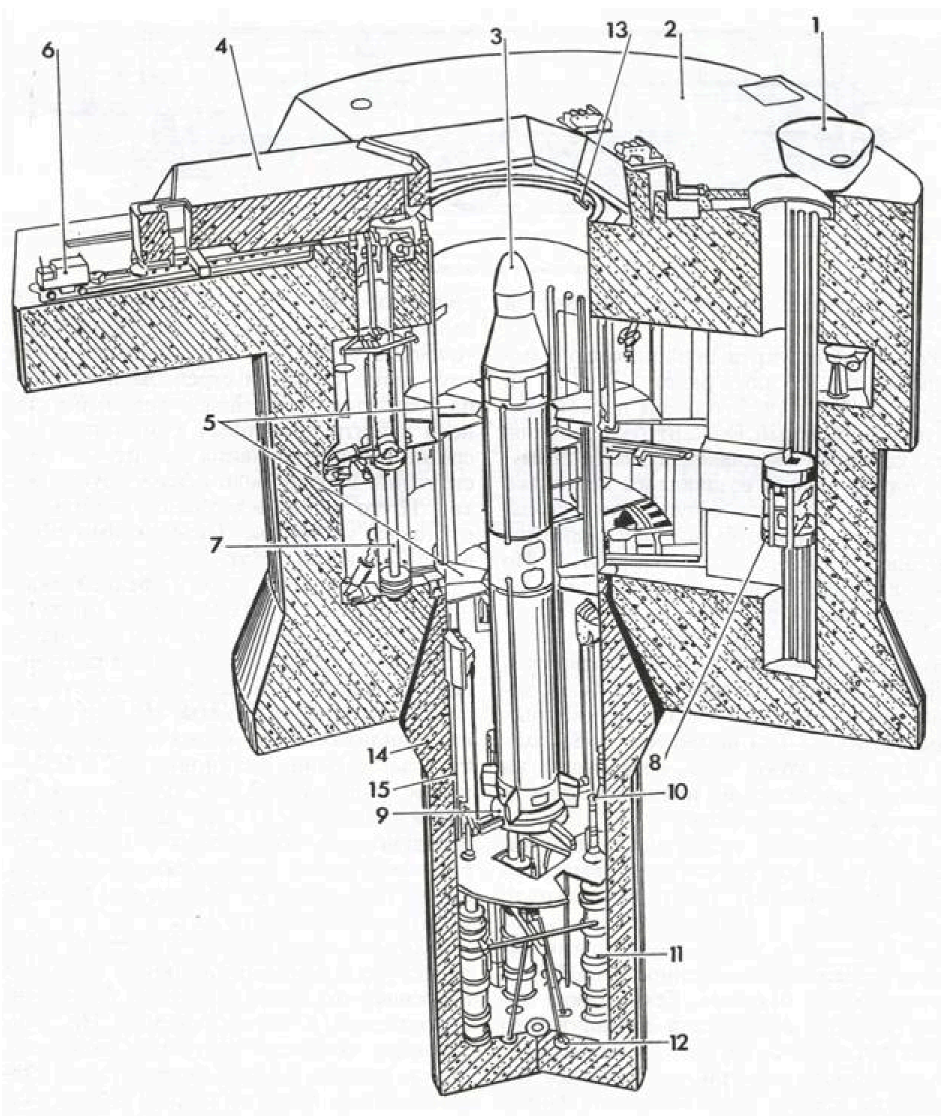
a shock-absorbing system above a container into which about 2 tons of a special water solution was poured. When the first-stage propulsion engine was launched, a cloud of gas-water vapor formed, which pushed the rocket out of the silo. For that time, the command post of this complex was a significant step forward in its design. It was created in accordance with ergonomic requirements, which provided exceptionally comfortable working conditions for combat crew personnel. In the mid-60s, in terms of security, it was in first place among all command posts of this level.

The developers of the French S-2 MRBM also created a silo launch complex for their rocket. Before the advent of the third generation missile launcher in the USSR and the modernization of the Minuteman launcher, it had the highest degree of protection. Organizationally, 9 OS launchers, part of one missile complex, were combined into one squadron, which had its own launch control point. In total, the French strategic nuclear forces have two squadrons deployed on the Albion plateau.

The design of the launcher is standard. Its depth is 23 m. The internal diameter of the mine shaft is 4 m. To increase stability during vibrations of the upper layers of the soil caused by a nuclear explosion, the shaft of the mine was protected by a head with a diameter of 15 m and a height of 14 m, which had two floors. Concrete and metal were widely used in the construction of silos. The shaft was closed from above with a protective roof weighing 140 tons, which was opened before launch by triggering a special powder charge. In order for personnel to get inside, a manhole was equipped. For ease of maintenance of the rocket and launcher systems, there were folding and stationary platforms. Possible vibrations were to be absorbed by group and local shock absorption devices. The rocket launched from the silo using its own propulsion engine.

When replacing the S-2 MRBM with the S-3, the silos were modified to meet new tactical and technical requirements. The reliability of some units and systems and the durability of the entire structure were increased, and neutron protection was installed. Currently, the security of the launcher in terms of pressure in the shock wave front is estimated at 50 kg/cm². The high degree of security of the launch control point was ensured by its successful placement in a long tunnel at great depths in the rocks. The launcher was connected to the launcher by underground cable lines, through which launch commands were transmitted.

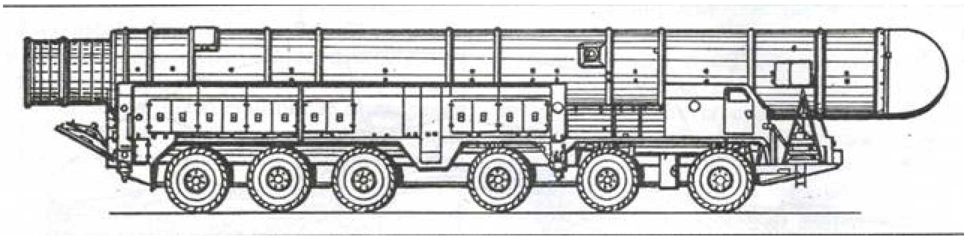
Chinese designers have achieved the least results in creating launch complexes. Their Dun-1 MRBMs were launched from launch pads located on stationary bunded launch pads. In constant combat readiness, a supply of rocket fuel components and rockets were stored in underground storage facilities. If necessary, the rockets were installed on the launch pad, pre-launch preparation was carried out, lasting about 2.5 hours, after which the rocket could be launched. The security of this launch complex was 0.2 kg/cm².



Section of the silo of the French S-2 MRBM

1 - concrete protective roof of the entrance hatch, 2 - eight-meter head of the shaft made of high-strength concrete, 3 - S-2 rocket, 4 - sliding protective roof of the shaft, 5 - first and second tiers of service platforms, 6 - protective roof opening device, 7 - counterweight shock-absorbing systems, 8 — elevator, 9 — support ring, 10 — rocket suspension cable tensioning mechanism, 11 — spring

limit switches for closing the protective roof, 14 — concrete shaft, 15 — steel shell of the mine shaft.



Self-propelled launcher MRSD "Pioneer"

The same type of launch was originally used for the Dun-2 and Dun-2-1 missiles. But in 1975, a semi-mobile basing option was introduced for the first, the essence of which boiled down to the following. For one rocket, several launch pads with launch pads were created, and the rocket could be alternately moved from one launch to another. But since all movements were carried out within one missile base, which had a rather limited size, it was not possible to achieve any noticeable increase in the degree of protection. There was no improvement in performance either. However, in 1988, out of 105 missiles of this type that were on combat duty, 40 were used in a semi-mobile version.

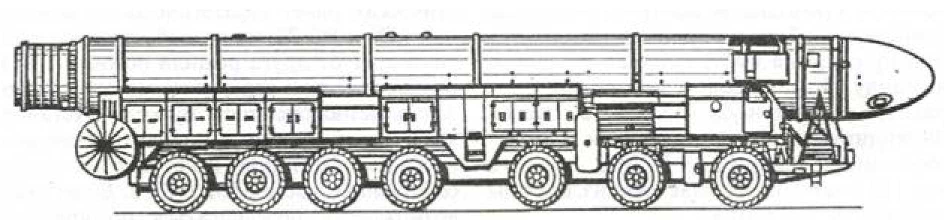
In the mid-80s, a launch complex with a single silo launcher was created for the first Chinese ICBM. But it was not distinguished by high combat and operational characteristics. The security of the silo was only 10 kg/cm². The technical readiness of the rocket reached 20 minutes, while the same indicator for modern Soviet and American missiles is calculated in several minutes. The reliability of the complex as a whole was also low. It should be admitted that this was notable progress for the Chinese rocket industry.

However, the laws of development of military systems are such that if defense is improved, then after a certain time the means of attack will necessarily improve. Nuclear weapons from ballistic missiles are no exception. A nuclear charge penetrating the ground was created, capable of hitting highly protected point targets, which, while improving shooting accuracy, called into question the further increase in the degree of protection of launch complexes through the build-up of protective structures. It was necessary to look for another way out. And it was found in the creation of mobile launchers. The Soviet Union was the first to acquire them.

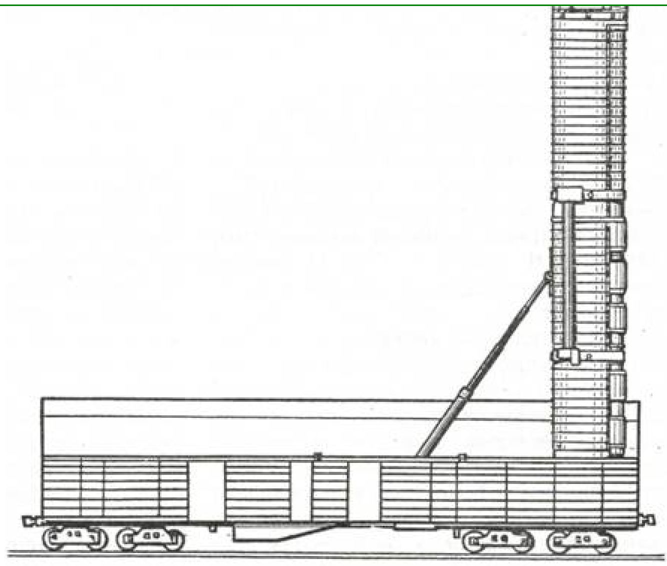
The Pioneer medium-range ballistic missile was placed on a MAZ-547 self-propelled chassis. On the same chassis, all the auxiliary systems were installed to ensure testing, pre-launch preparation and launch of the rocket. But, despite its solid weight and significant dimensions (installation length with TPK - 19.3 m, width - 3.2 m, height - 4.4 m, weight - more than 80 tons), the SPU moved quite briskly on roads with any surface, easily overcame meter-long fords and climbs of up to 15 degrees and had a turning radius of only 21 m.

When this missile system was created, its critics had a legitimate concern: what would happen to the missile and nuclear warhead in the event of an accident? But the design turned out to be so reliable that during 15 years of operation of 509 installations there was not a single case of destruction of a rocket or warheads, even in severe accidents and disasters.

Before launch, the SPU was hung on hydraulic supports, after which the container was raised to a vertical position. The launch was carried out remotely following commands from a mobile control point. The missile was ejected from the TPK by a powder pressure accumulator to a height of 30 m, after which the first-stage propulsion engine was turned on. In the process of eliminating these missiles, 72 launches were carried out in accordance with the provisions of the INF Treaty. All of them were successful, confirming the reliability of all systems of the missile complex. Possessing a low technical degree of protection (0.2 kg/cm²), self-propelled guns made it possible, nevertheless, in the event of a nuclear attack, to save some of the missiles for a retaliatory strike due to their maneuverability. But do not think that they did not have shortcomings. Large mass, dependence of shooting accuracy on the accuracy of determining the coordinates of the starting point, vulnerability to conventional weapons - all this is not a complete list of the inherent shortcomings of the SPU. And yet there were more advantages.



ICBM launcher RS-12M



Railway ICBM launcher RS-22B

The Americans also did not pass by the idea of mobile launchers. The missile system with the Pershing-2 MRBM has also become mobile. The missile was placed on a semi-trailer with a MAN tractor, which could travel at high speed on roads of any category. The length of the transport launcher was 9.6 m (length with the tractor - 15.39 m), width - 2.49 m, height - 2.86 m and weight 12 tons. The missile on the TPU was located openly, in a horizontal position. Containers with test equipment were installed on the semi-trailer, as well as a hydraulic pump system used to install supports and lift the rocket into a vertical position before launch. In peacetime, all combat and special vehicles and units of the missile system were located in boxes. The missile brigade, armed with the Pershing-2 MRBM, as already noted, was stationed in West Germany.

It was assumed that in wartime, missile batteries would be withdrawn to predetermined areas and begin preparing a nuclear strike. Before launch, the missiles were transferred to the firing position and connected via cable communication lines to a command post vehicle, the crew of which carried out and monitored the progress of pre-launch preparations and, upon receiving the order to launch, issued a launch command. Like the Soviet Pioneers, the Pershing 2 missiles were included in the list of those eliminated in accordance with the provisions of the INF Treaty, for which all 120 missiles were removed from Europe to the United States.

Mobile launchers have also been created for intercontinental missiles. The Soviet RS-12M was also placed on a self-propelled chassis based on the MAZ tractor. When creating it, the designers took into account the rich experience in operating the missile system with the Pioneer IRBM, which made it possible to significantly improve combat and operational characteristics and increase the reliability of the launcher systems and assemblies. However, the significant mass of the rocket affected its speed and maneuverability.

In both the USA and the USSR, when creating strategic ballistic missiles MX and RS-22, which were similar in their characteristics, their developers independently decided, in addition to silos, to place their products on mobile, but already railway, launchers. Several factors spoke in favor of this option. Firstly, the solid dead weight of MIRV-equipped ICBMs. Secondly, the ability to move along a wide network of railways at a much higher speed compared to mobile ground launchers, which made it possible to remove a missile system from an attack in a short time and save its missiles for a retaliatory strike.

In the Soviet Union, the DBK with railway launchers was adopted by the Strategic Missile Forces, and in the United States, after the signing of the START-1 Treaty, they suspended the development of such a installation to full readiness. Apparently, in the future, political factors will determine the development paths of strategic missile systems.

Chapter 5. Submarine ballistic missiles

Another large family of strategic ballistic missiles are sea-launched missile systems located on submarines. Their main component is the ship-borne missile system (KRS), which usually includes the following elements: a ballistic missile (BRIL); launch complex; missile fire control system; system for checking technical condition and preparing for launch; source data verification system; navigation data generation system; auxiliary ship support systems.

In terms of design, the launch complex, more than other elements of the launch complex, depends on the type of SSBN on which it is installed. It provides missile protection from vertical and horizontal overloads, launch or emergency ejection from the missile silo from a surface or submerged position. The missile silo, as an integral part of the boat's hull, formally belongs to the ship's systems. The launch cup with the necessary starting equipment is placed in it. The missile silo is usually located entirely inside the boat's durable hull.

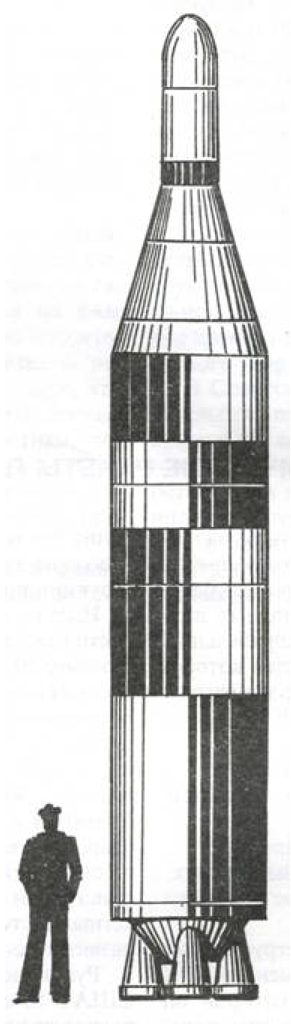
The design of submarine missile carriers had a significant influence on the development of SLBMs, but the opposite statement is also true. Therefore, the history of the creation of ballistic missiles for submarines will be presented together with the history of the development of the design of the latter.

The idea of building submarines with ballistic missiles on board matured in the mid-50s. By that time, ICBMs were not yet in service, but sufficient experience had been accumulated in creating medium-range missiles. The tempting idea of owning a missile submarine with nuclear weapons on board, capable of covertly approaching enemy shores and striking, has firmly taken hold of the minds of military strategists. Almost at the same time, the USSR and the USA began to create sea-based strategic missile systems, but their development took different paths.

In the 1950s, the leadership of the US Department of the Navy decided to acquire carriers of nuclear missile weapons at its disposal. And not without reason. In 1949–1953, the naval research laboratory conducted research on the problems of creating ballistic missiles for the fleet, as a result of which it was concluded that it was possible to create such weapons. By that time, nuclear-powered submarines had appeared, capable of moving secretly underwater for tens of days. Increased survivability of submarines, combined with a powerful surface fleet capable of ensuring the deployment of missile submarines in any area of the world's oceans, gave good trump cards to naval nuclear missile forces. As a result, a special report on this problem was prepared for President Eisenhower. At the direction of the head of the White House, a committee

The US Department of the Navy created a special projects department, which was tasked with leading the development of the missile system. In 1956, a contract was signed with Lockheed to develop a preliminary design. By the end of this year, tactical and technical requirements for the system were developed, and the optimal dimensions of the submarine, its missile compartment and missile were established. It was immediately determined that the missile system would be created in stages. The result of each stage was to be a rocket with better combat and operational characteristics than the previous one. As it turned out later, this was a far-sighted decision that made it possible to quickly deploy a modern fleet of missile submarines.

Initially, due to financial difficulties, it was proposed to create a rocket based on the Jupiter MRBM, work on which was in full swing at that time. But the fleet leadership was able to fight off this option. Given the difficulties with the development of liquid propellant engines, the bet was immediately placed on solid fuel engines, the production technology of which had been proven by 1957. At the same time, work was underway on a nuclear submarine project.



SLBM "Polaris-A1" (USA) 1960

In September 1958, flight tests of the rocket, designated Polaris-A1, began at the Eastern Test Site. The program ended with launches from the SSBN "J. Washington". A total of 42 test launches took place. In the fall of 1960, the missile system was put into service, and at the end of that year the first missile carrier went on combat patrol.

The Polaris-A1 SLBM is a two-stage missile with a sequential arrangement of sustainer stages. The motor housings of the supporting structure were made of special steel. The solid propellant rocket motors of the first and second stages each had four fixed nozzles with rotary deflectors, which ensured the creation of control forces in flight. Engine charges were made from mixed fuel consisting of ammonium perchlorate, polyurethane and aluminum with the necessary additives.

The second stage solid propellant rocket engine had a thrust cut-off device, which made it possible to vary the flight range. An inertial control system was installed on the rocket, which provided flight control in the active part of the trajectory and a firing accuracy of 3.7 km. The Mk1 nuclear monoblock warhead, which separated in flight, had a power of 0.5 Mt and could hit area targets at a distance of up to 2200 km from the launch site.

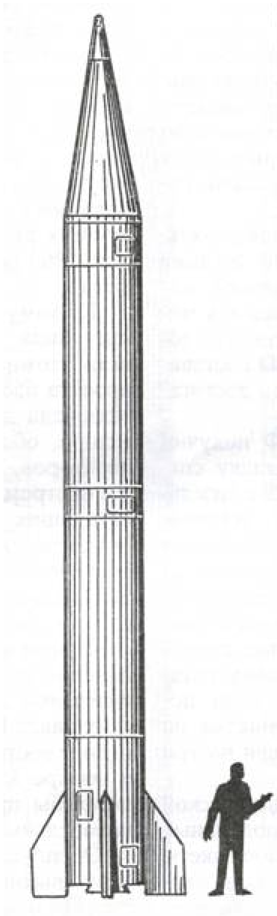
The carriers of these missiles were five J. Washington" (the name of the lead boat in the series). When it was created, the design of a Skipyak-type nuclear torpedo boat was taken as a basis. A 40-meter missile compartment was added behind the wheelhouse, in which 16 launch silos were placed. One nuclear reactor powered turbines with a power of 15,000 hp, which made it possible to reach a submerged speed of 24 knots. In addition to missile armament, the submarine was equipped with six 533 mm torpedo tubes with an ammunition capacity of 18 torpedoes.

Despite the fact that the working diving depth was 220 m, missiles could be launched from a depth of 25 m at a speed of no more than 5 knots and only sequentially. The first missile could launch 15 minutes after receiving the corresponding order.

On the first American SSBNs, compensation of horizontal and vertical loads was carried out using hydrodynamic shock absorbers. To prevent the rocket from hitting the walls, three rubber belts were used, which simultaneously acted as seals. With this design, it was necessary to provide a sufficiently large gap between the glass and the shaft, which did not allow using the entire volume of the launch shaft.

of the nuclear-powered icebreaker Lenin was underway. However, the improvement of the fleet's weapons was still carried out.

The Soviet leader, who had a special passion for rocketry, ordered the development of rocket weapons for the Navy. Particular attention was paid to the creation of missiles with a nuclear warhead for submarines. And since at that time in the USSR there was only one missile design bureau, S.P. Korolev, he was entrusted with the development of a ballistic missile. The deadlines were extremely strict. OKB-1, busy with work on intercontinental missiles, decided to take the path of adapting already created and tested missiles to new conditions. After consulting with the shipbuilders, the "royals" began modernizing the R-11M missile, which had suitable dimensions for placement on the submarines selected as possible carriers. This approach made it possible to meet the given deadlines, but could not ensure the creation of new effective weapons, which was later confirmed.



SLBM R-11FM (USSR) 1958

On September 19, 1955, the first test launch of the R-11 missile took place from a converted Project 611AB submarine, originally created for cruising operations in the ocean. She had a large displacement and powerful torpedo armament. Two vertical missile silos were installed in its wheelhouse. The first test launches showed that such a missile can be used in the navy, but it is necessary to create a reliable launcher. Despite the fact that this design was recognized as promising and the boat successfully passed tests, they did not begin to build a series, since the development of a more advanced Project 629 missile submarine had ended.

The missile, designated R-11FM in the Navy, is single-stage, with load-bearing fuel tanks made of a steel alloy. During its design and construction, the latest achievements in the field of rocket science and metallurgy were used. The use of light and durable materials made it possible to reduce the mass of the rocket to 5.5 tons. A liquid propellant engine was installed on the rocket, the fuel components of which were supplied to the combustion chamber not by a turbopump unit, but by a displacement system. Kerosene and nitric acid were used as fuel components, the ignition of which was ensured by a special starting fuel.

The low characteristics of the inertial missile control system, as well as the navigation system that served to determine the location of the boat at the moment of launch, did not allow achieving good shooting accuracy and the COE was about 7 km. The flight range reached 160 km.

In 1958, the Soviet Navy received the first specially built Project 629 missile submarine with a diesel-electric power plant, created on the basis of the Project 633 torpedo submarine and inheriting from it almost all systems and equipment unchanged. The overall length of the wheelhouse body was slightly increased. The torpedo armament and power plant were left unchanged. Until 1961, 23 submarines were built. Before the adoption of the R-13 SLBM, they carried three R-11FM missiles.

The next Soviet ballistic missile developed for submarines was the R-13, based on the R-5M missile. The work on its creation was entrusted to the then young designer V.P. Makeev. He had all the makings of a great and talented leader, and when the government decided to organize a new design bureau for the design of SLBMs, S. Korolev recommended his candidacy as chief designer. Subsequently, the team of this design bureau became the main developer of sea-based ballistic missiles.

Work on the new bureau began in the mid-50s. The R-13 missile was not much different in design from the R-5M. It was longer than Polaris with almost the same diameter, but the flight range of the Soviet missile was much shorter than that of the American one.

The inertial control system ensured a firing accuracy of 4 km, which, in combination with a 1 Mt nuclear monoblock warhead, made it possible to strike area targets. Like the R-11FM, the R-13 missile could only be launched from a surface position. This reduced the combat value of the new submarines. And even greater unification of the design with the R-5M in this case did not play a noticeable positive role. But there were no better missiles yet, and the R-13 entered service with the fleet in the fall of 1960.

By this time, the first Soviet nuclear missile submarine, Project 658, had been tested and entered service. Its power plant included two pressurized water nuclear reactors, which provided the operation of turbogenerators. In total, in the period 1958–1962, 8 submarines of this

In addition to three R-13 ballistic missiles, the boat carried powerful torpedo weapons: six 533-mm bow and four 356-mm stern tubes for firing anti-submarine and anti-ship torpedoes.

The operation of the lead submarine K-19 revealed a number of significant design flaws. In 1961, during a Northern Fleet exercise called "Arctic Circle," a port side reactor accident occurred on it. The death of the boat was prevented, for which a temporary cooling system for the emergency reactor had to be installed directly in the ocean. Eight people who responded to the accident and received large doses of radiation died after returning to base. Later, a standard system for emergency water flushing of the reactor was installed to remove excess heat. K-19 turned out to be unlucky. In February 1972, a fire broke out on it, killing 28 submariners. But, despite all the shortcomings, Project 658 submarines were in combat service until the early 90s.

In 1960, flight tests of the Polaris-A2 rocket began in the United States, which lasted only one year. The missile was intended to equip five Ethen Allen-class SSBNs, which were a development of the J. Washington". High-strength steel was used in the design of the new missile carrier, which made it possible to increase the working diving depth to 400 m. The increase in the size and displacement of the boat while maintaining the power plant led to a slight decrease in the full submerged speed, which, in general, did not matter much. On the new SSBNs, the number of missile silos remained the same, but the number of torpedo tubes was reduced. The remaining four were quite enough to ensure self-defense. The first missile carrier went on combat patrol in 1962, and the entire series entered service within two years.

The Polaris-A2 SLBM differed from its predecessor in the longer second stage. The solid propellant rocket engine of this stage has been redesigned. The body is made of fiberglass. Increased fuel supply. Four nozzles were made deflectable. The firing accuracy and power of the nuclear warhead were inherited from the Polaris-A1 missile, and the maximum flight range increased by 600 km.

By 1964, the US Navy had 10 submarine nuclear missile carriers with 160 missiles, which in their tactical and technical characteristics significantly exceeded Soviet missile submarines. Despite the fact that there were 31 such boats in the Soviet Navy, they were armed with only 93 missiles, which were also inferior to the Polaris in terms of firing range and reliability.

Given the almost complete superiority of the American Navy over all other navies, the US leadership decided to turn nuclear-powered missile submarines into the main component of the nuclear triad.

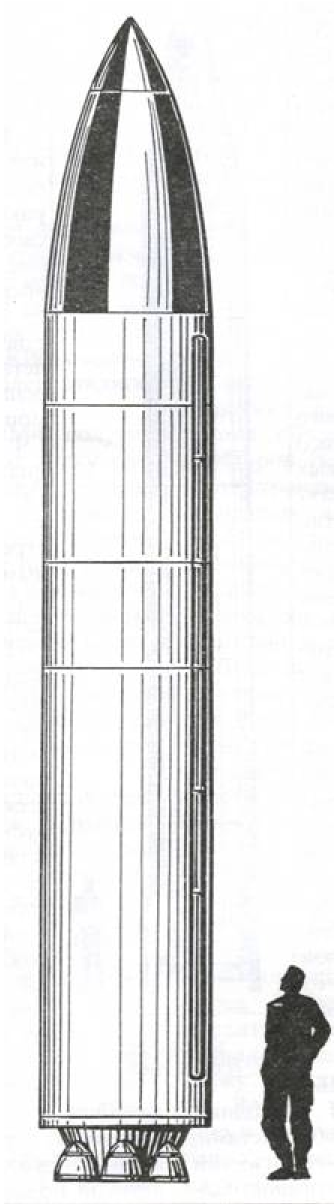
SLBM R-21 (USSR) 1963

In May 1963, the R-21 ballistic missile began to enter service with Soviet missile boats instead of the R-13. In terms of its technical level, it was a significant step forward, but only in comparison with its Soviet predecessors. Its flight range was 1,300 km when equipped with a warhead with a power of 1 Mt and 1,600 km with a warhead with a power of 0.8 Mt. An inertial control system with improved characteristics ensured a shooting accuracy of 2.8 km. The main advantage of the rocket was that it could be launched from a depth of 40 m.

8 nuclear and 13 diesel boats of Project 629 were re-equipped with the new missile. At the same time, the latter were modernized. Since the R-21 rocket was large, the contours of the conning tower had to be slightly changed. A telescopic mast was installed on its left side. We also replaced some of the electronic equipment with more advanced ones. Six modernized diesel submarines were transferred to the Baltic, where they remained on combat duty until the end of the 80s. Others became part of the Pacific Fleet. In March 1968, one of them (K-129) was believed to have died as a result of a collision with an American submarine that was tracking a Soviet submarine. But even with new missiles, Soviet missile submarines were still inferior to American ones in their tactical and technical characteristics.

AZ, were carried out for two years. The bodies of both stages were made of fiberglass. Due to the use of new fuel based on polyurethane, ammonium perchlorate and nitroplasticizer, it was possible to significantly increase the firing range without changing the geometric dimensions. The first stage solid propellant rocket engine had four rotating nozzles. Four fixed nozzles were installed on the second stage rocket engine and control forces were created by injecting freon into the supercritical part of the nozzles. The freon supply was stored in a toroidal tank, which was filled at the factory. An improved inertial control system provided flight control in the active part of the trajectory and a shooting accuracy of 2.3 km. The missile carried a monoblock nuclear warhead with a capacity of 1 Mt. As these missiles were received from industry, all previously released modifications were removed from service and transferred to reserve.

In addition to the new missile, the US Navy received a new Lafayette-class SSBN. By the time the flight tests of the missile were completed, there were eight missile carriers of this project in service, which were armed with Polaris-A2 missiles. The submarines were created taking into account the accumulated experience in operating SSBNs of the first and second stages. Much attention was paid to reducing the boat's own noise, as well as the ability to actively fight enemy anti-submarine forces.



SLBM "Polaris - A3 (AZT)" (USA) 1964

The submarine was equipped with a water-cooled S5W nuclear reactor. A new propeller design was used. The combat capabilities of SSBNs have increased significantly. For self-defense, the boat used not only multi-purpose torpedoes, but also Sabrok missiles fired through torpedo tubes. To control missile fire, they installed the Mk88 combat system, which made it possible to prepare the first missile for launch in 15 minutes. The interval between launches of subsequent missiles has been shortened. The SLBM was fired using the steam-gas method. A total of 31 SSBNs were built. The last 12 were somewhat different in the composition and placement of equipment (officially they were listed as B. Franklin-class SSBNs). Their noise level has decreased.

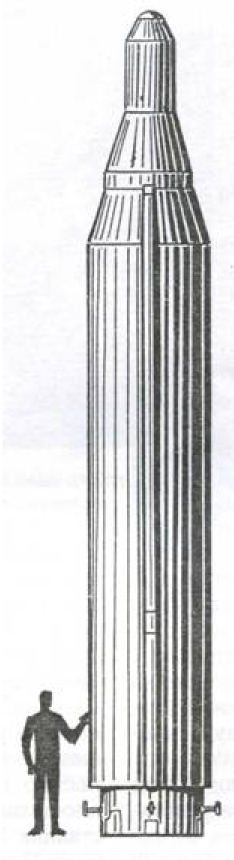
But the development of the Polaris missile system did not end there. A further way to expand the combat capabilities of these missiles could be to equip them with multiple warheads of a dispersive type. Between November 1966 and 1968, nine test launches were carried out to test the new generation warheads. Upon completion, the replacement of the Polaris-AZ missiles with the AZT modification began. They were distinguished by a modified control system and MKZ MIRV with three dispersible warheads with a capacity of 200 kt each. The warheads of one missile could hit targets over an area of 8 km^2.

In 1968, the first British SSBN of the Resolution class went on combat patrol. The government of this state, building its nuclear policy, relied on its American partner. After the appearance of the Polaris SLBM, the British military leadership proposed to its government to build a fleet of

American technical assistance in the creation of SSBNs.

"Resolution" in its technical characteristics is close to "Lafayette". The lead boat in the series was laid down in June 1964 at the Vickers Armstrong shipyard. Its construction took five years. The hull of the boat at the bow and stern had a shape close to cylindrical, which, according to the developers, was supposed to reduce noise at low speeds typical for combat patrols. The bow horizontal rudders were placed in the bow of the boat's hull, while in existing SSBNs of other countries they were located on the deckhouse. The PWR1 water-cooled nuclear reactor produced steam for two turbines driving a single propeller. The missile compartment and missile control systems were completely taken from the Americans.

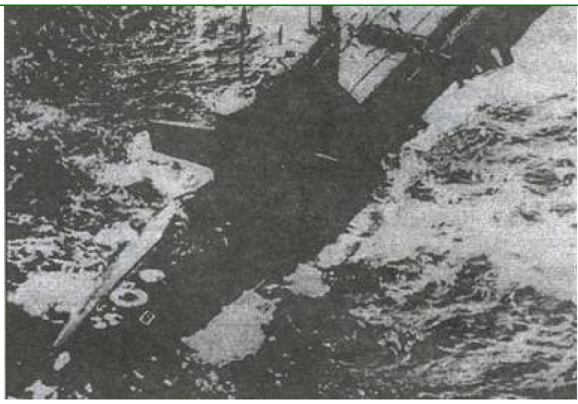
The British equipped their missile carrier with the most advanced hydroacoustic and radio-electronic equipment at that time. Anti-submarine and anti-ship torpedoes could be used to protect against surface and underwater enemies. It was armed with American-made Polaris-AZT missiles. The lead ship was followed by three more of the same type. The fleet received the last boat in 1969.



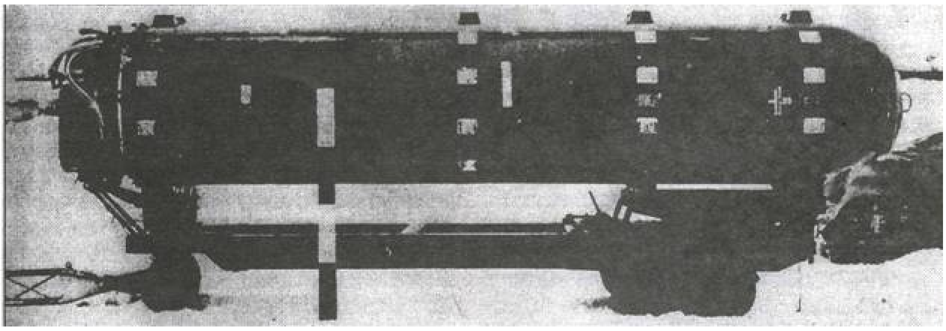
SLBM R-27 (USSR) 1966

To combat Soviet submarines, the Americans and their allies began to create systems to control their movement. In accordance with the Caesar program, which began in the late 50s, the US Navy deployed a network of hydrophone detectors on the continental shelf along the eastern coast of the continent, on the Hawaiian Islands and underwater elevations of the world's oceans. Subsequently, it was significantly expanded and modernized. In the 60s, the SOSUS system was created, the task of which was to detect Soviet submarines in the Atlantic. To prevent their breakthrough from the Barents Sea to the North Atlantic, an anti-submarine barrier was created. Hydrophones were installed between Greenland, Iceland and the Shetland Islands. This space is constantly monitored by anti-submarine aircraft and submarines of the United States and NATO countries. The implementation of new theoretical developments has made it possible to significantly expand the arsenal of submarine detection means. Anti-submarine forces have received magnetometers, as well as devices that respond to changes in water temperature when passing an underwater object with a large mass. In addition, special search groups of surface ships are constantly used to search for submarines.

To break through such a train, new boats were needed. In 1967, the first Navaga-class SSBN (Project 667A) entered the Soviet Navy. This submarine missile carrier had a power plant with two nuclear reactors, allowing it to reach underwater speeds of up to 30 knots. The boat's armament consisted of 16 R-27 SLBMs and 6 533 mm torpedo tubes with multi-purpose torpedoes for self-defense. The hull design allowed diving to depths of up to 400 m.



Navaga-class SSBN of the Northern Fleet K-219, which surfaced after a missile explosion in the silo



SLBM R-27 without warhead

Navaga was similar in appearance to American SSBNs and had a low missile compartment superstructure. For its time, this submarine was quite successful and was built in a large series (32 units) for the Northern and Pacific fleets from 1966 to 1974. The high underwater speed made it possible to escape from the enemy. However, the noise of the boat remained high, despite the use of multi-bladed propellers. Theoretically, as the number of blades increases, the pressure on them is distributed more evenly, due to which significant noise appears only at high speeds.

A significant drawback of boats of this type remained ballistic missiles, or rather, their insufficient flight range. This forced SSBNs to choose patrol areas close to likely targets, which significantly complicated the solution to the problem of ensuring the combat stability of Soviet missile carriers.

The R-27 missile, the submarine's main weapon, was developed at the Makeev Design Bureau. Single-stage with a liquid-propellant rocket engine, it had a length of 9.65 m, a maximum diameter of 1.5 m, and a launch weight of 14.2 tons. High-boiling oxidizer and fuel were used as fuel components, which ignited upon mutual contact. The inertial control system ensured a target accuracy of 1.9 km, which, in combination with a 1 Mt nuclear warhead, made it possible to confidently hit an area object. The flight range was 2400 km.

The R-27 was ejected from the submarine's launcher, which was underwater, using a steam-gas mixture. To create the necessary pressure at the moment of firing, four obturation belts were attached to the rocket body. The launcher had guides to ensure movement and additional stability of the rocket. In 1973, an improved R-27 missile with a flight range of 3000 km was put into service, and a year later a missile equipped with a MIRV with two dispersible warheads with a capacity of 200 kt each was adopted.

SLBM "Poseidon-SZ" launches from an underground launcher

Missile carriers of the Navaga type were in combat fleets until the mid-90s. One SSBN was lost in 1986. On October 3, on a boat patrolling 480 miles northeast of Bermuda in a submerged position, sea water rapidly began to flow into the missile silo, which crushed the missile body. Ignition of fuel components led to an explosion. The crew and ship were probably saved from instant death by the ship's robust design and the fact that a significant portion of the explosion energy went upward. The sailors managed to force the submarine to float, but on October 6 it sank. Four submariners were killed.

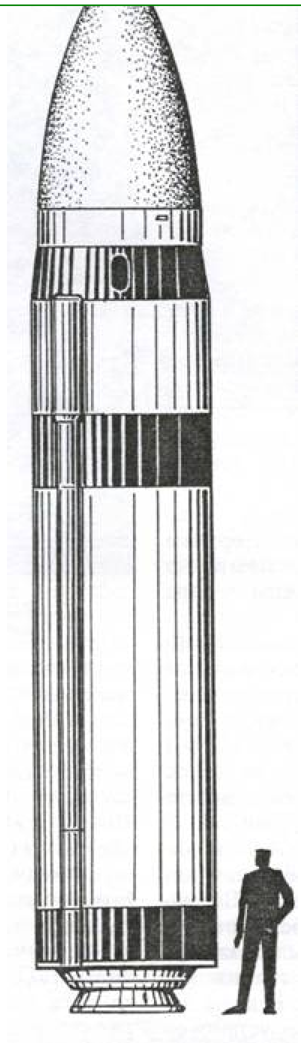
While the Soviet Navy was rapidly replenished with new missile carriers, the United States began testing a new missile, designated Poseidon-SZ. This SLBM was supposed to ensure a qualitative transformation of the naval component of the strategic nuclear forces. For the new missile, the individually targeted MIRV MK17 was developed, which was tested jointly with the MK12 MIRV. All work was carried out without much haste. The task was too responsible. Flight development tests began in August 1966. The missiles were launched from ground-based launchers at the Eastern Test Site. The program provided for 25 launches, including from a submarine. In July 1970, the tests were successfully completed.

The Poseidon-SZ SLBM is a two-stage missile with a sequential arrangement of stages. The first stage solid propellant rocket engine, developed by Hercules, had a fiberglass body. The nozzle, deflected by a hydraulic system, was made of aluminum alloy. To reduce the overall length of the rocket, it was "sunk" inside. It was pulled into the working position before turning on the engine. In flight, to ensure rotation along the angle of rotation, a system of micronozzles was used that used gas generated by a gas generator. The second stage solid propellant rocket engine developed by the Thiokol company was structurally different from the first stage engine in the nozzle block. Its nozzle is partially recessed and made of fiberglass with a graphite liner. The fuel used in both solid propellant engines is a mixed one, consisting of ammonium perchlorate and hydrocarbon fuel with aluminum additives. The main stages, the instrument compartment and the MIRV were connected using adapters made of aluminum alloy. The fire method was used to separate the stages. A charge was attached to the front of the adapters, which was triggered at the moment of separation. This method was used on almost all American SLBMs.

The inertial control system was located in a sealed instrument compartment. The use of a new three-axis GPS and an electronic computing unit made it possible to achieve a shooting accuracy of 0.8 km. Subsequently, after modernization of the element base and the introduction of the Loran-S and Transit satellite systems, this figure was increased to 470 m. The control system provided flight control in the active part of the trajectory and disengagement of warheads. Excess heat from the control unit was removed by a thermostating system.

The multiple warhead of the rocket consisted of a combat compartment and a propulsion compartment. The combat compartment was designed for 10 individually targeted warheads with a yield of 0.05 Mt each. With such combat equipment, the flight range was 4600 km. An option to equip the MIRV with six warheads of the same power has also been tested. The missile's flight range reached 5,600 km. The propulsion system of the propagation stage, which ensures the guidance of all combat equipment at targets located over an area of 10 thousand km^2, consisted of a solid fuel gas generator, a system of eight nozzles providing control over the angle of rotation, and eight nozzles that created forces at the pitch and yaw angles. Let us note that such a solid propellant propulsion system is more complex in design than an installation with a liquid propellant rocket engine of a similar purpose.

The US leadership authorized and allocated funds for a program to rearm 31 Lafayette-class SSBNs with Poseidon missiles. The missile carriers of the early projects decided to leave the Polaris-AZT SLBMs. It was necessary to redo the launch silos, since the new missile had a larger diameter, to replace the missile firing control system, which was caused by the need to solve problems that had not previously been addressed (for example, retargeting MIRV warheads) and to modernize electronic equipment. The implementation of this program dragged on until 1979, while the Poseidon production program was completed in 1975. In 1991, there were more than 560 missiles of this type on combat duty and in reserve.

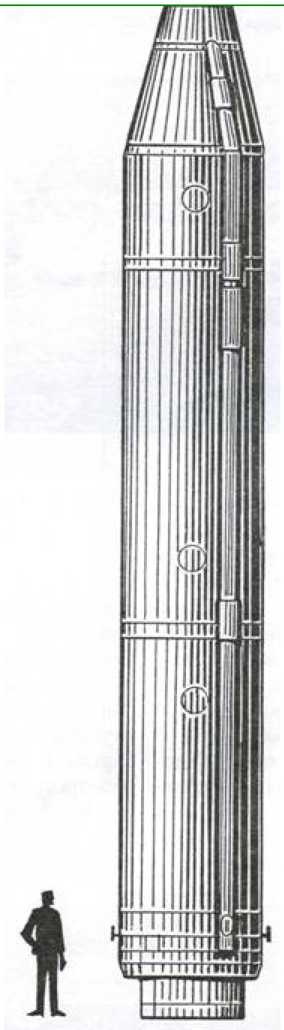


SLBM "Poseidon-SZ" (USA) 1971

Advances in the field of rocketry achieved by French scientists and designers in the late 60s made it possible to create their own SLBM, designated M-1. The flight test program for this missile included 35 launches, including 20 from the specially built experimental submarine Zhimnot. The military leadership of France, when creating its own strategic nuclear forces, decided to place the main emphasis on their naval component. Taking into account the forecast for the development of technology and American experience, it was decided to gradually increase the combat power of nuclear missile carriers. The five SSBNs planned for construction within ten years were to be equipped with more advanced missiles as they entered service. The lead SSBN in the series, Redoutable, was transferred to the fleet in 1971, and the next one, Terrible, was equipped with the M-1 SLBM. This two-stage rocket with solid fuel engines had a launch mass of about 18 tons. It was created using the same technologies as the S-2 MRBM. The step bodies were made of special steel. The solid propellant rocket engines each had four rotating nozzles, the deflection of which was carried out by a hydraulic system. The fuel supply ensured flight to a range of 2600 km. The missile was equipped with a monoblock nuclear warhead with a capacity of 0.5 Mt. The inertial control system controlled the flight in the active part of the trajectory. At the same time, its characteristics made it possible to achieve a shooting accuracy (CAO) of 2.3 km.

In 1974, the M-2 SLBM was adopted, which was a further development of the M-1. By increasing the fuel supply to 6 tons in the second stage, it was possible to increase the flight range to 3200 km. The use of more advanced devices in the control system improved the shooting accuracy (CA) to 2 km. Both of these French SLBMs were launched from a depth of 25 m. The first missile could be prepared for launch in 20 minutes, and subsequent ones within 15–20 seconds. Missiles from launchers were fired using the steam-gas method. According to their combat characteristics, the M-1 and M-2 could reliably hit area targets.

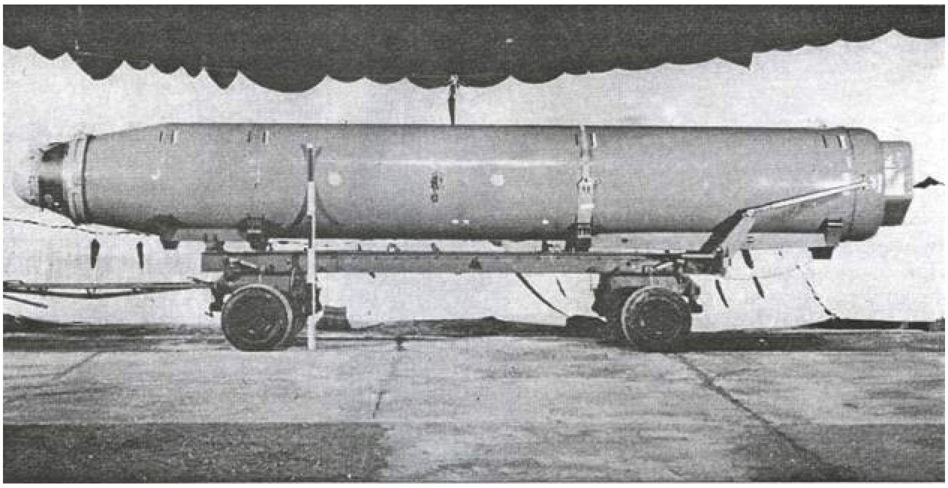
French Redoutable-class SSBNs were built in Cherbourg. The third boat, named "Fudroyant", was armed with an M-2 missile. All of them had a nationally developed water-cooled nuclear reactor with two turbogenerators supplying energy to the main electric motor. There was also a diesel generator with a power of 850 kW, which made it possible to ensure the return of the ship to its home base in the event of failure of the main propulsion system. Like all Western missile submarines, the French had one propeller. Electronic and hydroacoustic equipment in combination with fire control systems provided solutions to the entire range of tasks facing the crew. To determine the location of the ship, inertial navigation systems and an anti-aircraft periscope were used (in the case of orientation by the stars).



SLBM RSM-40 (USSR) 1973

In 1973, the Murena-class SSBN (project 667B), armed with 12 RSM-40 SLBMs developed by Makeev Design Bureau, appeared in the combat strength of the Soviet Navy. The two-stage rocket with liquid fuel engines and a sequential arrangement of stages had a length of 13.9 m and a maximum diameter of 1.8 m. The inertial control system ensured the delivery of a monoblock warhead with a power of 1 Mt to the target with a circular probabilistic deviation of 1.6 km. The missile had a flight range of 7800 km. Its modification, adopted for service in 1974 and equipped with a lighter monoblock warhead with a power of 0.8 Mt, could hit targets at a distance of up to 9,100 km. However, the dimensions of the rocket have not changed.

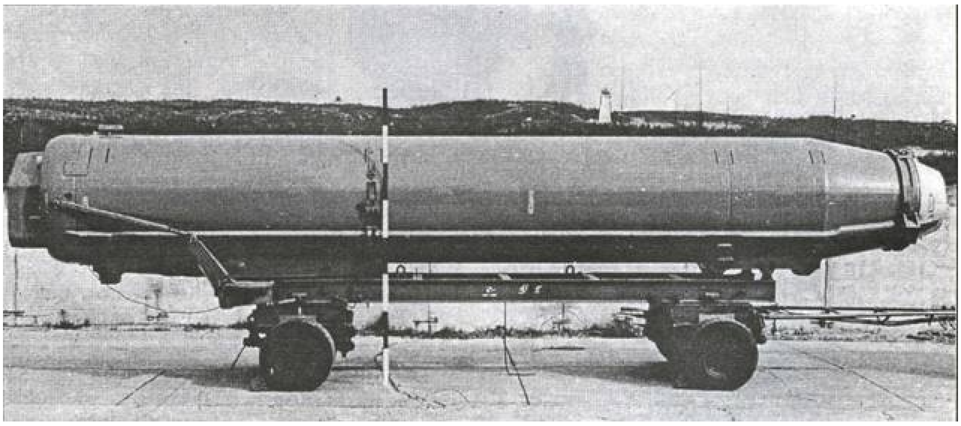
A significant increase in the size of the rocket required the construction of a new submarine. "Moray eel" became it. When creating it, the shipbuilders took all the best from the Project 667A missile carrier. The missile compartment has undergone a radical redesign. The number of launch shafts was reduced to 12, increasing their diameter. The height of the superstructure behind the wheelhouse has increased significantly and the silhouette of the submarine has acquired the "hump" characteristic of boats of this series. Two nuclear reactors powered the turbines. Despite its impressive size, the boat could reach underwater speeds of up to 25 knots.



SLBM RSM-40 (left view)

far from their native shores. The increase in the missile's flight range made it possible to select patrol areas for missile carriers closer to their bases, where the surface fleet could provide fairly reliable cover. The submarines also had their own means of self-defense - torpedo weapons. But it was not possible to overcome such a disadvantage as a high noise level and to equal the American missile carriers in this indicator. Project 667B submarines were built from 1972 to 1974 in a large series. In total, the Northern and Pacific fleets received 18 ships of this type. However, with a greater length, the Morays carried four fewer missiles than the Navagas. At the request of the military, shipbuilders undertook to correct this deficiency. The simplest path was chosen. By increasing the length of the boat, it was possible to place 16 launch silos. This is how the Project 667BD ("Murena-M") SSBN appeared, of which four units were built.

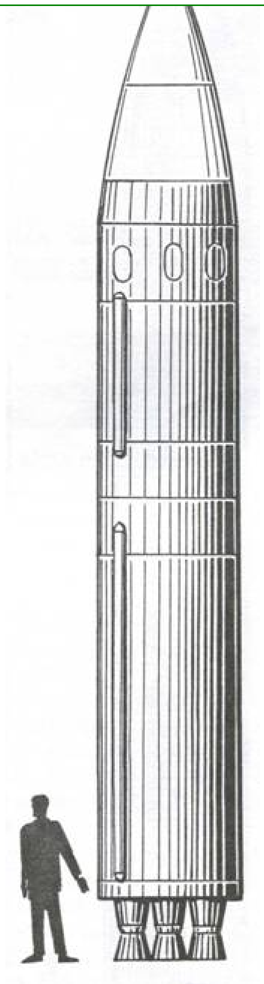
In the mid-70s, the Soviet Navy received a submarine missile carrier, named Navaga-M. As it turned out later, he remained in the singular. This boat owed its birth to the persistent desire of high leadership circles to equip the fleet with solid-fuel SLBMs. There were several reasons for this. Firstly, the example of the Americans, who had only solid fuel missiles in their arsenal, was haunting. Secondly, Soviet submariners wanted a less potentially dangerous missile, since it was believed that aggressive liquid components are more explosive than solid rocket fuel.



SLBM RSM-40 (right view)

The chief designer of the leading design bureau for the design of naval ballistic missiles, Makeev, strongly defended the opinion that the creation of such a missile was inappropriate. But his opinion was not taken into account. The design bureau received the task, enshrined in the relevant government decree. The team coped with the task, but, as one would expect, given the given tactical and technical characteristics of the submarine and missile, as well as the technology existing at that time for creating solid propellant rocket engines, it was not possible to achieve significant improvements in performance.

The two-stage R-31 missile had a launch weight of 26.9 tons, which was almost twice the mass of the R-27, while the maximum flight range increased by only 900 km. At the same time, neither the power of the warhead nor the shooting accuracy increased. The characteristics of the submarine, which inherited everything from its predecessor except the missile compartment, did not improve. The number of launch silos had to be reduced to 12. For that time, an SSBN with such a missile could easily be considered obsolete and a series of similar ships was not built. Navaga-M was in service with the Northern Fleet until the end of 1991.



SLBM M-20 (France) 1976

In 1976, the third stage SLBM, which received the designation M-20, was supplied to equip the French naval nuclear forces. In terms of its technical level, it was significantly more advanced than its predecessors. The new missile was a kind of hybrid of French sea- and land-based ballistic missiles. The first stage remained the same as that of the M-2, and the second stage and the warhead were entirely taken from the S-3 MRBM. The body of the second stage solid propellant rocket engine was made of fiberglass and had one fixed recessed nozzle. The control was carried out by injecting freon into the supercritical part of the nozzle.

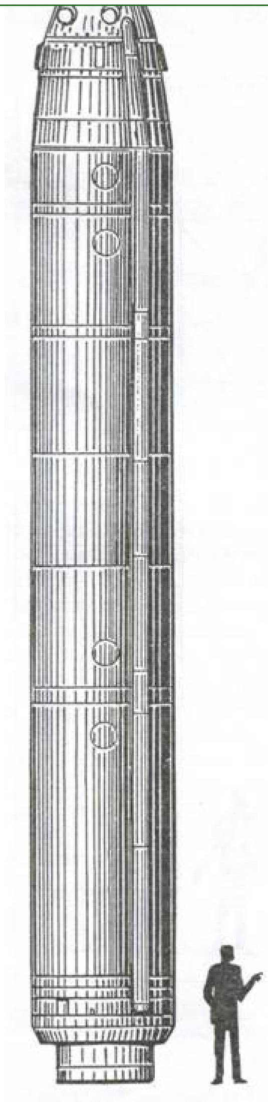
The inertial control system has been significantly improved. It was equipped with an electronic computing unit, and the GSP with a unit of high-speed gyroscopes. As a result, the firing accuracy (CAO) was 0.9 km. The powerful monoblock thermonuclear warhead of the megaton class, in addition to the combat charge and its automation, also contained a set of means to overcome missile defense. Moreover, its developers were guided by the characteristics of the Soviet missile defense system.

The M-20 SLBM gradually replaced earlier models on the three SSBNs that entered the fleet's operational composition until 1976. The last two missile carriers in the series received not only new missiles, but also nuclear reactors with liquid metal coolant. With their commissioning, France became third in the world in terms of the strength of its naval nuclear forces.

In the Soviet Union in the 70s, in parallel with work on a solid fuel rocket, the Makeev Design Bureau was developing a new SLBM with liquid fuel engines. It was supposed to be equipped with individually targeted MIRVs and compete with the Poseidon. The design was based on the quite successful RSM-40 rocket. The inertial control system was redesigned to solve the problems of warhead disengagement, while simultaneously improving the characteristics of the electronics and the astro-correction unit, which made it possible to achieve a firing accuracy (CAO) of 0.9 km.

In the combat compartment of the missile's launch stage, designated RSM-50, three nuclear warheads with a capacity of 0.5 Mt each, capable of reliably hitting area targets at ranges of up to 6,500 km, were placed. In 1978, the RSM-50 modification with a monoblock warhead with a power of 450 kt was put into service. A year later, the RSM-50 missile with seven individually targeted warheads with a capacity of 100 kt each began to be supplied to equip Soviet missile carriers. Due to the fact that the length of the new ballistic missiles has increased by 1.5 m compared to the RSM-40, it was necessary to build new submarines capable of deploying them. Shipbuilders have developed a project for an underwater missile carrier under the designation 667BDR.

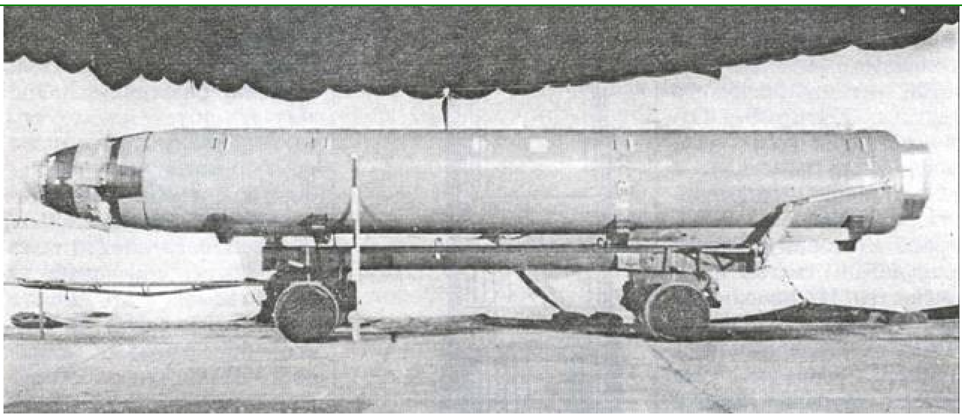
It became a further continuation of its predecessors. No significant design changes were made. The overall height of the missile compartment increased by 2.5 m, which naturally led to an increase in displacement. Navigation and radio-electronic equipment have become more advanced. The design of the stern rudders has changed. The submarine has become less noisy.



SLBM RSM-50 (USSR) 1976

SSBNs of this type are called “Squid”. Between 1976 and 1984, the Northern and Pacific fleets received 14 such nuclear-powered ships from shipbuilders. With their commissioning in the field of naval strategic nuclear weapons, the Soviet Union and the United States could have a certain equality. The RSM-50 missile, while superior in flight range and warhead power to the American Poseidon SLBM, was inferior to it in the number of warheads and in firing accuracy. The RSM-40 was superior in almost all respects to the Polaris-A2 and Polaris-AZ with monoblock warheads. True, American SSBNs were superior to Soviet ones in a number of combat characteristics, especially in the efficiency of electronic equipment and the level of their own noise, while being inferior to them in the total number of combat units. In 1975, the United States had 656 SLBMs of all types, and the USSR - 784. In terms of the number of warheads on them, the American side far exceeded the Soviet side. But equality could not be achieved, and for this reason.

In November 1966, the leadership of the US Department of Defense decided to form a temporary committee, designated "Strat-X", whose tasks were to develop and select promising concepts for missile weapon systems. As a result of research conducted in 1966–1967, the committee presented a report that substantiated the need to create a new sea-based missile system with high operational and technical characteristics. Work on its creation has been carried out since 1968, according to two programs. The first provided for the creation of a new SLBM with a firing range of 9-10 thousand km and a new SSBN with 20 or 24 launch silos, the second was to increase the firing range of the Poseidon missile. In July 1969, the leadership of the Ministry of Defense considered that these programs duplicated each other and funding for the modernization of Poseidon was stopped. In September 1971, a report was submitted to the Minister of Defense for consideration, outlining possible ways forward. After its discussion, an option was chosen based on the developments carried out within the framework of the above-mentioned programs. The approval of the report in October of the same year was the formal beginning of the program for the acquisition of a new weapon system.



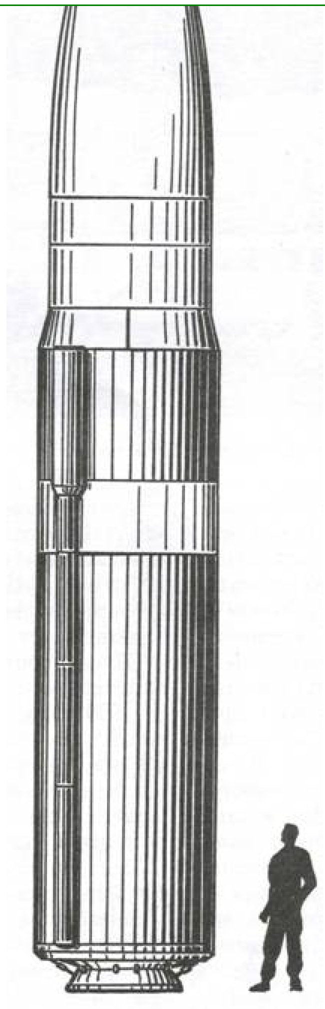
SLBM RSM-50 (left view)

In view of the importance of the tasks assigned to the new missile system, a decision was made to accelerate work on the program, which was given the name "Trident," and to increase allocations for its implementation. It was immediately decided that work on the creation of the Trident-1 ship-based missile system would serve as the basis for the subsequent development of the Trident-2 complex. The decision to move the program into full-scale development was made in October 1973, however, actual work began in full due to financial restrictions imposed by Congress in March 1974. The first flight tests took place in January 1978. A year earlier, the Minister of Defense decided to switch to the production of Trident-C4 missiles.

The launches were carried out from the Eastern Test Site. In total, until September 1979, 25 launches were carried out, including several from SSBNs. In the same year, the number of missiles that were to be built was finally determined. They planned to purchase 570 missiles to equip 12 Lafayette-class SSBNs (192 units) and eight newly built Ohio-class missile carriers (also 192 units). Production of the missiles was supposed to be completed in 1986. In industry, work was carried out by a group of contractors. The lead company for the missile was Lockheed, and the lead company for the submarine was General Dynamics.

The Trident-C4 SLBM is a three-stage missile designed according to a sequential stage design. In this case, the third stage solid propellant rocket engine occupies a volume along the longitudinal axis of the rocket from the upper bottom of the second stage engine to the top of the fairing. The structural elements of the MIRV type MIRV are located around this rocket engine. This design made it possible to reduce the overall length of the rocket. The steps were connected to each other by means of transition compartments. The main stage engines have cocoon-type housings made by winding from Kevlar-49 organic fiber. The nozzles, deflected at an angle of 7 degrees, are placed in flexible supports with a hydraulic drive. Solid propellant rocket motors of the first and second stages are equipped with a thrust cut-off system. Their maximum operating time is 60 seconds. The separation of all stages is "hot". The third stage has a braking motor.

The missile's flight is controlled and the warheads are guided using the on-board astro-inertial control system MKB, built on the basis of the on-board central control system and a set of command instruments. Astrocorrection is carried out after the operation of the main stages is completed, for which a maneuver is performed in order to capture the selected luminary, located close to the zenith in the target area, with astro sensors. After the correction, the stage of breeding the warheads begins. The use of thin-film hybrid microcircuits made it possible to reduce the mass of the electronic control units by 50%, which gave an "increase" in flight range by 220 km. It is interesting to note that it was originally planned to have a firing error (CEP) of only 470 m. However, the successes achieved in the implementation of a research program aimed at increasing the firing accuracy of SLBMs, which was completed in the second half of the 70s, and the implementation of its results gave the ability to achieve a CEP value within 300 m with a flight range of about 8000 km.



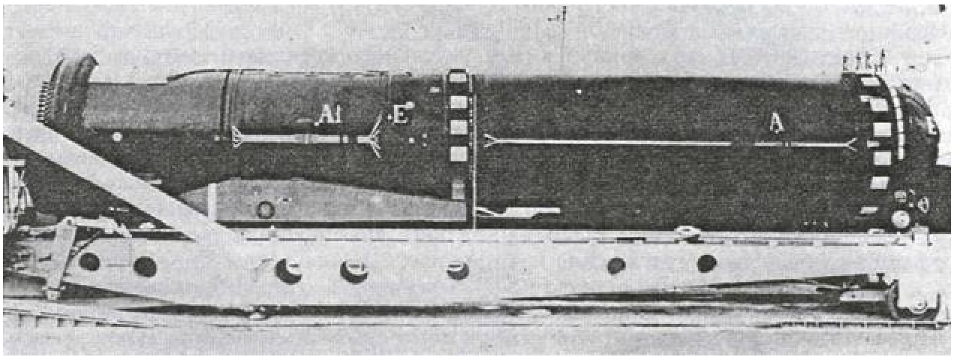
SLBM "Trident-C4" (USA) 1979

The missile was equipped with a Mk4 multiple warhead, structurally consisting of two subsystems: a combat compartment and a propagation stage. It is covered by an ogival-shaped fairing with a large bluntness, which is caused by dimensional restrictions. In order to reduce drag, the fairing is equipped with an aerodynamic needle that can be extended in flight, which provided an “increase” in range by 550 km. The combat compartment housed eight individually targeted warheads with a yield of 100–150 kt each. The propulsion system and missile control system were placed at the breeding stage. Even during the period of development work on the Trident-C4 SLBM, research was carried out with the aim of creating maneuvering warheads capable of evading the weapons of anti-missile systems, and they were even tested. However, information about their production did not appear in the press.

The first carriers of the Trident-C4 missiles were 12 SSBNs of the B series. Franklin", as the most advanced of the Lafayette family and having a shorter service life. Naturally, they have undergone major repairs and modernization. A new missile control complex and launch complex were installed. A number of boat systems have been improved. The program to re-equip these submarines with new missiles, which began at the end of 1978, ended in 1982. In 1979, the American Navy's newest nuclear-powered missile submarine, Ohio, was laid down - the lead in a large series of similar SSBNs created in accordance with the Trident program. Research and development work on the new generation missile carrier project has been carried out since October 26, 1972, and the construction order was issued on July 25, 1974. During its creation, the latest achievements of science and technology in the field of underwater shipbuilding were used in such issues as optimization of hull contour shapes, protection of hull structures, mechanisms and equipment from underwater explosions, increasing stealth and reducing acoustic, magnetic, hydrodynamic, radiation, thermal and other physical fields.

A pressurized water reactor of the S8G type was installed on the boat, which ensured the operation of turbines with a capacity of 60,000 hp. With. The underwater speed was 25 knots. The height of the missile silos on the Ohio is 13.95 m, and on the Lafayette - 11.4 m, which is slightly greater than the diameter of the pressure hull. The shaft is closed from above with a hydraulically controlled lid with a seal. The silo housing has hatches for access to the rocket during maintenance. A pipeline for supplying a vapor-gas mixture is mounted to the lower bottom, with the help of which the rocket is ejected. To launch a rocket from an unflooded silo, a membrane assembly is used that separates the cavity of the launch cup from the aqueous environment when the missile silo lid is open. The destruction of the membrane at the moment of launch is carried out using a pyrotechnic system. The vapor-gas mixture is formed in a special chamber, into which combustion products from a solid fuel gas generator and water are supplied in certain proportions. When a certain pressure value is reached, the steam gas is supplied to the ejection chamber located under the rocket. The rocket can be launched at intervals of 15–20 seconds from a depth of up to 30 m, at a speed of up to 5 knots and with waves up to 6 points. At the same time, the process of transferring the Trident-1 missile system from constant readiness to one-minute readiness for launch takes about 15 minutes. The power of the computer complex of the missile fire control system makes it possible to adjust flight missions simultaneously for all missiles during pre-launch preparation, which makes it possible to achieve high flexibility in the selection of targets. The use of correction sources for navigation data of the Loran-S and Transit systems, as well as the use of gravimetric equipment, makes it possible to determine the location of the submarine with high accuracy. Due to the introduction of the ESGN system based on highly stable gyroscopes with an electrostatic rotor suspension, the accuracy of maintaining parameters by the on-board navigation system has increased by 4–6 times.

"Ohio" differs from its predecessors in its greater power supply, increased patrol speed (maximum low-noise speed), and more advanced on-board systems and complexes. The duration of operation without recharging the reactor has increased to 9 years (at Lafayette - 5 years). A 13-fold reduction in noise was achieved thanks to the introduction of natural coolant circulation in the primary circuit of the nuclear power plant effective methods for processing hydroacoustic information, the target detection range has been increased by more than 2 times. The creation of such an advanced submarine missile carrier, naturally, required significantly greater costs. The cost of the Ohio-class SSBN was $1.3–1.5 billion, which was more than ten times the purchase price of the Lafayette submarine. To this day, Ohio holds first place in the world in terms of the number of SLBMs deployed on it - 24 units and is the most advanced in its class.



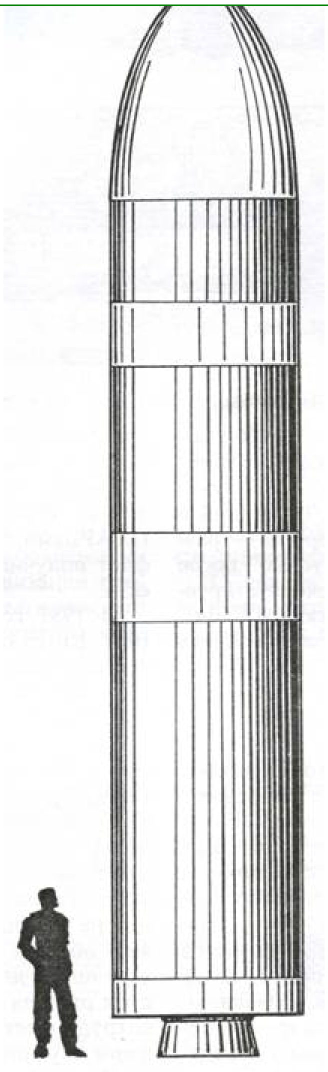
SLBM PCM 52 (USSR) 1983

With the advent of the Trident missile system, a lag in a number of combat indicators of all naval strategic missile systems in the Soviet Union and France sharply became apparent. Information received from overseas about the creation of SLBMs with high tactical and technical characteristics greatly alarmed the Soviet military and political leadership. Under these conditions, the task was set to build SSBNs with equal capabilities in the shortest possible time. Easy to say, but difficult to do, especially in a limited time. And yet the shipbuilders found a way out. Project 941 of a heavy submarine cruiser of a unique design was created. Instead of one traditional pressure hull, it had two located next to each other. Each of them housed 10 missile silos, a nuclear power plant with control and maintenance systems. The main command post was placed in a separate durable cylinder with a six-meter diameter. The strong hulls were covered with a single lightweight body. According to the developers, the missile carrier was supposed to be able to return to base even if one of the hulls was hit. The unusual architecture of the ship was complemented by missile silos located in front of the wheelhouse for the first time. SSBNs of this type have become the largest submarines in the world. With a length of 170 m, their width exceeded 24 m, which is almost 2 times more than that of the Ohio. The Soviet submarine missile cruiser was named "Akula". But it turned out that he gained worldwide fame under a different name - “Typhoon”. Its armament consisted of 20 RSM-52 ballistic missiles and 8 torpedo tubes, suitable for the use of a variety of torpedo and missile weapons. The first of the Typhoons went on combat patrol in 1983, and the Northern Fleet has six such boats in total.

Three-stage, with a sequential arrangement of stages, RSM-52 was specially created for SSBNs of this type at the Makeev Design Bureau. It became the first Soviet sea-based strategic missile, which was produced in a large series. The missile has a very respectable mass - 84 tons, with a total length of 16 m. It is equipped with a multiple warhead with 10 individually targeted warheads with a power of 100 kt each.

The inertial control system ensures a hit accuracy of no more than 0.5 km when firing at a maximum range of 8300 km. It should be noted that while rocket designers created a rocket whose combat characteristics were quite comparable to the American Trident-1, the shipbuilders were unable to completely solve the problem. With the same length, the Ohio carried four more missiles than the Typhoon, had a smaller displacement and, most importantly, had better survivability.

In 1980, the British modernized the SSBN missile weapons. With the help of the Americans, they carried out a number of works to improve the performance of their Polaris. The Polaris-AZTK modification differed from the previous model in the second stage, control system and combat equipment. Due to the installation of a new GPS and electronic computer unit, the shooting accuracy (CA) was increased to 0.5 km. The missile was equipped with an individually targeted MIRV with increased protection developed by the British. Its combat platform was equipped with six nuclear warheads with a yield of 50 kilotons each. Their deployment at the target was ensured by a liquid fuel propulsion system. Testing of the rocket began in September 1977 and was carried out at US test sites. In November 1980, a test launch took place from a submarine located off the coast of Florida. It was successful and the missile was put into service. The measures taken made it possible to significantly increase the combat effectiveness of the UK's naval nuclear missile forces. However, this was a half-measure that made it possible to maintain the average level for another ten years.



SLBM M-4 (France) 1985

In 1985, France's missile-carrying submarine fleet was replenished with a new boat, the Enflexible, created for the M-4 SLBM, which had been in development since 1975. In November 1980, flight tests of this rocket began at the Biscarrosse missile test site. In March 1982, the first test launch took place from the Zhimnot submarine, and a total of 17 launches were carried out. M-4 is a three-stage rocket, with a sequential arrangement of stages. The body of the first stage solid propellant rocket engine is made of steel. Charge of mixed solid fuel of bonded type. One rotatable, recessed titanium alloy nozzle was pulled into position just before the engine was turned on. The difference between the second stage engine was that its housing was made of fiberglass. The third stage engine was developed specifically for this rocket. Its body was wound from Kevlar-49 fiber. An inertial control system, built on the basis of a three-axis GPS and an on-board digital computer complex, provided flight control and deployment of warheads. Firing accuracy was 0.45 km.

The missile was equipped with a multiple warhead with six individually targetable warheads with a power of 150 kt each. They could hit targets at ranges up to 4,500 km from the launch site. In terms of its technical characteristics, the new SSBN differed little from the Redoutable-class submarines. The displacement increased, which was a consequence of the increased mass of 16 missiles compared to the M-20 SLBM. In addition to torpedoes, the new boat was equipped with Exocet anti-ship missiles. Electronic and hydroacoustic equipment was updated.

Since 1986, the Soviet Navy began to be replenished with new Dolphin-class SSBNs (project 667BDRM). It’s not hard to guess that this was another modification of the first-born of this project, “Moray Eels.” The Dolphins owe their appearance, on the one hand, to the adoption of the successful RSM-54 SLBM, created at the Makeev Design Bureau, and on the other hand, to the disappointment that came after comparing the characteristics of the operational Typhoons and the American Ohio. In addition, the Typhoons turned out to be very expensive ships.

SLBM RSM-54 (USSR) 1986 (left view)

The RSM-54 ballistic missile was created taking into account the rich experience accumulated by the design team over more than 25 years of work on this topic. The rocket is three-stage, with a sequential arrangement of stages. Liquid rocket engines with high performance were used as propulsion engines at all stages, which made it possible to achieve a flight range of 8300 km. At the same time, the launch weight was only 40.3 tons, i.e. 2 times less than that of the RSM-52. The missile was equipped with a multiple warhead with four individually targeted warheads with a power of 100 kilotons each. The astroinertial control system ensured a shooting accuracy of about 0.5 km.

The new Soviet submarine missile carrier has not undergone major design changes compared to the Project 667BDR boats. Once again, the height of the missile compartment and the overall length of the hull were increased. The torpedo armament has changed somewhat. More advanced equipment has appeared. But, most importantly, it was possible to significantly reduce the noise of the submarine, which was immediately noticed by American anti-submarine officers. "Dolphins" became the last Soviet GTLARBs. In total, by the end of 1991, the fleet received 7 missile carriers of this project.

In 1987, the first Chinese nuclear-powered missile submarine with ballistic missiles on board, called Xia, entered service with the Chinese Navy. In terms of its tactical and technical characteristics, it is close to the American submarine J. Washington". But the Chinese missile carrier carried only 12 missiles and was built almost 30 years later, when boats with such characteristics were already obsolete. In the design of the Chinese missile carrier, there is a noticeable orientation towards French SSBN projects: the same hull contours, power plant, propulsion system, arrangement of weapon systems. This shows the consequences of cooperation between shipbuilding firms of the two countries.

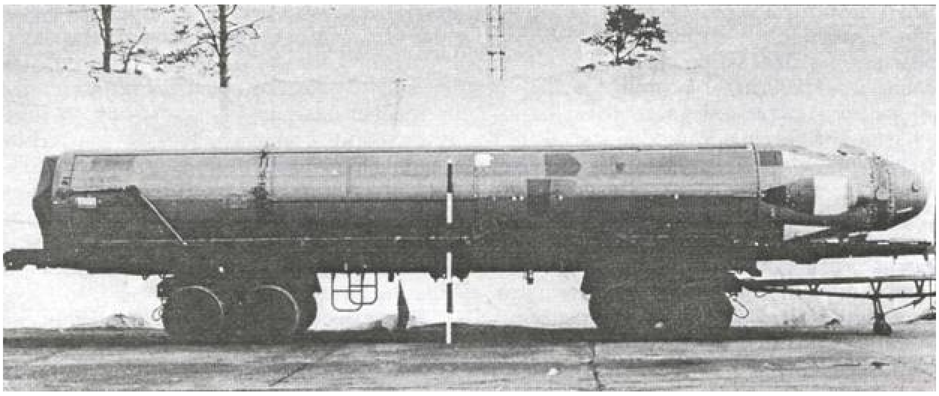
The boat was laid down in 1978 and launched on April 30, 1981, but later significant difficulties arose with the development of the Julan-1 SLBM missile system installed on it. The first test launch of this missile, carried out on board an experimental submarine in 1985, was unsuccessful. Only in September 1988, after the SSBN had been commissioned, flight tests of the missile were completed and it entered service. Two-stage, with solid fuel engines, it had a launch weight of about 14 tons. The flight range was just over 2000 km. The Chinese SLBM has an inertial control system, the characteristics of which allow it to deliver a megaton-class monoblock nuclear charge to the target with an accuracy of 1.3 km.

Despite the fact that in terms of the level of technological performance and tactical and technical elements, the Xia SSBN is inferior to similar boats of the “nuclear club” countries, its commissioning marked the creation of the naval component of China’s strategic nuclear forces triad, and its deployment in the Yellow and East China Seas significantly increases Chinese military potential in the Asia-Pacific region.

The latest SLBM in the world to enter service in the late 90s was the American Trident-C5. It was created in accordance with the plan for the second stage of the Trident program. It was assumed that in its creation promising technologies from the 80s would be used. In 1974, the US Secretary of Defense ordered the Department of the Navy to develop and submit for consideration a draft plan for the creation of a Trident-2 ship-based missile system. The start of its development was authorized by the Deputy Minister of Defense in 1976, but due to financial difficulties the deadline had to be postponed. The actual implementation of the program began in October next year. By March 1980, experts prepared for consideration by Congress the “SLBM Modernization Program,” which substantiated the need to create a new missile for the Ohio-class SSBN.

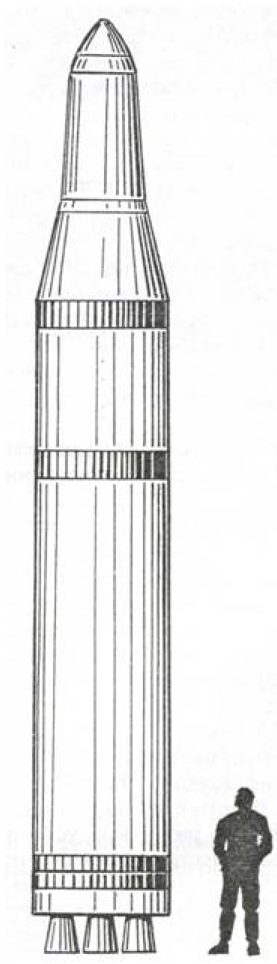
Until the fall of 1983, research was carried out on the design of the rocket. Various options for design and layout schemes were evaluated. The type of head part was selected. In September of the same year, the Minister of Defense decided on full-scale development, which was planned to be completed by the end of 1989. The Trident-C5 SLBM production program was repeatedly adjusted in connection with changes in plans for the development of sea-based missile forces. In the end they settled on the number 800. But as it turned out, this figure was not the last. The signing of the START I Treaty in July 1991 changed the situation radically.

On January 15, 1987, the first launch of the Trident-C5 missile was carried out from the Eastern Test Site. The flight test program included 20 launches from a ground-based launcher and 5 from an SSBN. It was completed only in February 1990. During this time, 19 launches were carried out from the launch pads of the test site (3 of them ended in failure) and 9 from the Tennessee submarine (2 unsuccessful). Test launches from a submarine revealed the need to make changes to the design of the first stage and launch silo, which ultimately delayed the missile's acceptance into service and reduced its flight range. The designers had to solve the problem of protecting the nozzle block from the effects of the water column that occurs when the SLBM emerges from under the water.



Structurally, the Trident-C5 SLBM is not much different from the Trident-C4 ballistic missile. The RDT'G housings of the first and second stages are made of graphite-epoxy material, which provides higher strength characteristics than the use of Kevlar. The third stage engine housing is made of a composite material based on Kevlar-49 fiber.

All rocket engines have a lightweight oscillating nozzle that provides pitch and yaw control. Nozzles and nozzle attachments are made of new composite materials that are resistant to high pressure. An increase in the mass of the fuel of the first and second stages, as well as the use of rocket fuel with a high specific impulse, made it possible to increase the firing range by approximately 2000 km compared to the Trident-C4 with the same thrown mass. The maximum duration of operation of the solid propellant rocket engines of the first and second stages is 65 seconds, the third - 40 seconds. The missile is equipped with a multiple warhead of the MIRV Mk4 or Mk5 type, which includes an instrument compartment for the control system, a combat compartment, a propulsion system and a nose fairing with an aerodynamic needle. The combat compartment can accommodate 8 warheads with a yield of 475 kt each or up to 14 warheads with a yield of 100 kt each. The propulsion system of the MS consists of four solid fuel gas generators and control nozzles.



SLBM "Juilan-1" (China) 1987

The Mk7 control system is designed to control the flight during the active part of the trajectory and the stage of disengagement of warheads. Its main part is located in the instrument compartment of the propagation stage. The use of a complex of command instruments with high performance and astro-correction made it possible to achieve high firing accuracy (CAO) of 120 m, which is comparable to the firing accuracy of the latest Russian ground-based ICBMs and far exceeds the firing accuracy of Russian SLBMs.

Trident-C5 ballistic missiles can only be based on Ohio-class SSBNs, due to the size of the missile. Each boat has 24 missile silos. The distance between adjacent shafts on one side is 0.8 m, and between the shafts on the left and right sides is about 1 m. The design of the shaft on Trident missile system submarines is the same everywhere. But for each type of rocket, its own launch tube is installed (can be installed afloat at the pier). It is rigidly mounted in the shaft, which does not require a large gap between the walls of the glass and the shaft to accommodate hydraulic shock absorbers. For normal release of the rocket from the launcher, the latter is inflated with nitrogen to a pressure equal to the pressure of the sea water. If the start is cancelled, the pressure is released.

The complex of systems of this missile carrier ensures the performance of combat missions anywhere in the world's oceans, including in the high Arctic latitudes, and the firing accuracy combined with powerful warheads allows the missiles to effectively hit small-sized protected targets, such as silo-based ICBM launchers, command centers and others military targets, something that no other SLBM in service can do. The modernization capabilities inherent in the development of the Trident-2 missile system, according to American experts, make it possible to keep the missile in service with naval strategic nuclear forces until 2005, and for Ohio-class submarines even longer.

In 1990, two missile carriers with Trident-2 missiles on board went on combat patrols, and two more the following year. All of them have the ability to deliver the first disarming strike, that is, to “knock out” the strategic means of a retaliatory strike of any enemy.

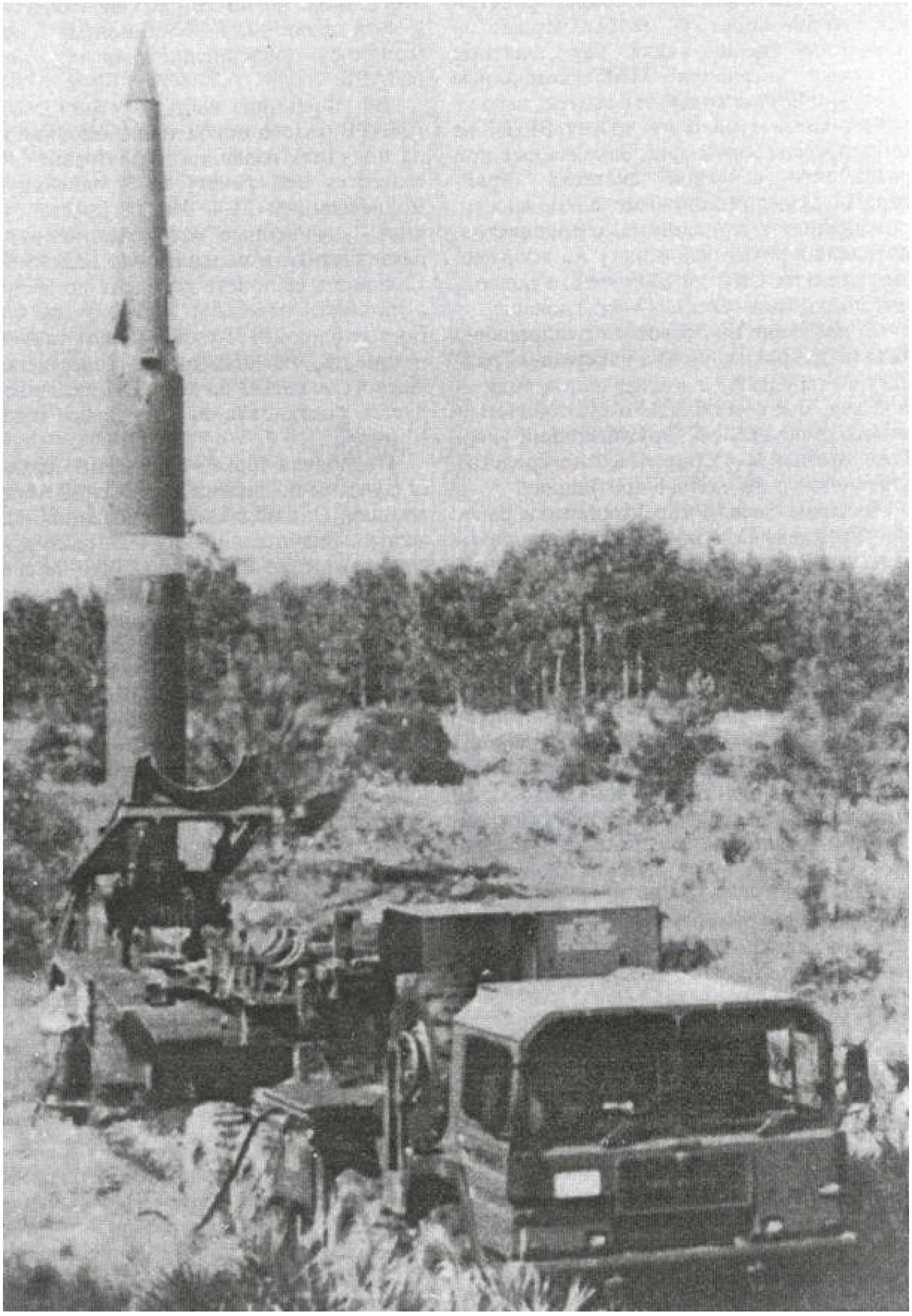
The high combat characteristics of the Trident-C5 missile interested the British government, which was faced with the problem of replacing the Polaris-AZTK SLBMs, which were completely obsolete by the end of the 80s. After consultations with the American side, it was decided that the United States would provide the requested missiles to its ally. Since the submarines of the Resolution project, due to their characteristics, cannot be converted into Tridents, the British had to start developing and building a missile carrier of a new project, called Vanguard. Unlike the

A new generation of SSBNs is being built in France. The lead boat was named "Triumphant". It is being created for the M-5 missile, which is a modification of the M-4. The new missile will have improved performance characteristics and increased reliability. Its flight range has been increased to 6,000 km, and its firing accuracy (CA) has been increased to 0.4 m. Although MIRV warheads have the same power, their degree of sophistication is much higher. At the beginning of the 21st century, it is planned to install the M-5 missile on these boats.

The submarine "Triumphant" is created taking into account the latest achievements of science and technology. It has increased survivability. The size and displacement of the submarine increased significantly, which required the installation of more powerful machines. With the commissioning of these missile carriers, the effectiveness of France's strategic nuclear forces will increase several times.

In China, work is also underway to create a new type of SSBN (project 094). It will be armed with 16 Julan-2 SLBMs, the tactical and technical characteristics of which are expected to be better than those of the Julan-1.

The constant improvement of SLBMs and their carriers indicates that they will remain the leading component of the strategic nuclear forces of nuclear countries not only until the end of the century, but also in the next 10 years of the new century.



Launcher with the PERSHING-2 missile

Applications

Annex 1
Designations of Soviet (Russian) strategic ballistic missiles

	Rocket name				
Type	Domestic			Foreign	
	Military*	Industry	According to the Agreements	USA	NATO

BR	R-2	8Zh38		SS-2	Sibling
SLBM	R-11FM	8K11		SS-1B	Scud-A
IRBM	R-5M	8K51		SS-3	Shyster
SLBM	R-13			SS-N-4	Sark
IRBM	R-12	8K63		SS-4	Sandal
IRBM	R-12U	8K63U		SS-4	Sandal
IRBM	R-14	8K65		SS-5	Skean
IRBM	R-14U	8K65U		SS-5	Skean
SLBM	R-21			SS-N-5	Serb
ICBM	R-7	8K71		SS-6	Sapwood
ICBM	R-7A	8K74		SS-6	Sapwood
ICBM	R-16	8K64		SS-7	Saddler
ICBM	R-16U	8K64U		SS-7 Mod.2	Saddler
SLBM	R-27		RSM-25	SS-N-6	Sawfly
ICBM	R-9A	8K75		SS-8	Sasin
SLBM			RSM-40	SS-N-8	
ICBM	R-36	8K67		SS-9	Scarp
ICBM	UR-100	8K84		SS-11	Sego
ICBM	UR-100UTTH	8K84M		SS-11 Mod.2	Sego
ICBM	UR-100K	15A20	PC-10	SS-11 Mod.3	Sego
ICBM	UR-100U	15A20U	PC-10	SS-11 Mod.4	Sego
ICBM	RT-2P	8K98P	PC-12	SS-13	Savage
ICBM	MR-UR-100	15A15	RS-16A	SS-17	Spanker
ICBM	MR-UR-100U	15A16	RS-16B	SS-17 Mod.2	Spanker
SLBM	R-31		RSM-45	SS-N-17	Snipe
ICBM	R-36M	15A14	RS-20A	SS-18	Satan
ICBM	R-36MU	15A18	RS-20B	SS-18 Mod.2	Satan
ICBM		15A18	RS-20V	SS-18 Mod.3	Satan
SLBM			RSM-50	SS-N-18	Stingray
ICBM	UR-100N	15A30	PC-18	SS-19	Stilleto
ICBM	UR-100NU	15A35	PC-18	SS-19 Mod.2	Stilleto
IRBM	"Pioneer"	15Zh45	RSD-10	SS-20	Saber
IRBM	"Pioneer UTTH"	15Zh53	RSD-10	SS-20 Mod.2	Saber
SLBM			RSM-52	SS-N-20	Sturgeon
SLBM			RSM-54	SS-N-23	Skiff
ICBM		15Zh60	RS-22A	SS-24	Scalpel
ICBM		15Zh61	RS-22B	SS-24 Mod.2	Scalpel
ICBM	RT-2PM "Topol"	15Zh58	RS-12M	SS-25	Sickle

-given from the book by A.V. Karpenko "Russian missile weapons 1943–1993."

Appendix 2
Performance characteristics of submarines carrying SLBMs

Country, name of the lead boat (project)	Year of delivery Year of entry into combat patrol	Displacement, t: surface. supply	Main dimensions, m: length x width x maximum draft	Type of power plant total power, l. With.	Working immersion depth, m	Submarine speed, knots	Armament		Total number of submarines built
							torpedo quantity TA caliber, mm	missile launcher number x SLBM type at the time of commissioning	
USA:									
"J. Washington"	1959	5700	116.4x10.1x8.8	nuclear power plant	220	24	6	16 x "Polaris-A1"	5
	1960	6700		15000			533		
"Ethen Allen"	1961	6955	124.9x10.1x9.1	nuclear power plant	400	23	4	16 x "Polaris-A2"	5

				power plant				AZ",	
	1964	8250		15000			533	(later "Poseidon")	
"Ohio"	1981	16800	170.7x12.8x10.8	nuclear power plant	450	25	4	24 x "Trident-S4"	8
	1982	18700		60000			533		
Great Britain:									
"Resolution"	1967	7000	129.5x10.1x9.1	nuclear power plant	220	23	6	16 x "Polaris-A3T"	4
	1968	8000		20000			533		
"Vanguard"	1993	14500	150.0x12.8x10.0	nuclear power plant	400	23	4	16 x Trident-C5	1+3*
	1994	15500		35000			533		
France:									
"Redoutable"	1970	7900	128.7x10.6x9.8	nuclear power plant	200	23	4	16 x M-1, (M-2, M-20)	5
	1971	9000		20000			533		
"Enflexible"	1985	8000	128.0x10.6x9.8	nuclear power plant	250	23	4	16 x M-4	1
	1986	9000		20000			533		
"Triumphant"	1994	12500	128.7X10.6X9.8	nuclear power plant	400	24	4	16 x M-4	1+3*
		14500		40000			533		
China:									
"Xia"	1985	6000	113.0x10.0x10.0	nuclear power plant	300	23	4	12 x Julan-1	1
	1988	7000		20000			533		

Country, name of the lead boat (project)	Year of delivery Year of entry into combat patrol	Displacement, t: surface. supply	Main dimensions, m: length x width x maximum draft	Type of power plant total power, l. With.	Working immersion depth, m	Submarine speed, knots	Armament		Total number of submarines built
							torpedo, number of TA caliber, mm	missile, number of launchers x SLBM type at the time of commissioning	
THE USSR:									
project 611AB	1955	2100	90.0x7.9x6.0	diesel	200	16	10	2 x R-11FM	1
("Zulu")**	1958	2500		6000			533		
project 629	1958	2350	98.0x8.2x6.5	diesel	230	14	10	3 x p-13	23
("Golf-1")	1959	2650		6000			533		
project 629A	1964	2900	99.0x8.2x8.1	diesel	300	12	6	3 x R-21	12
("Golf-2")	1964	3600		6000			533		
project 658	1959	5000	115.0x9.0x7.2	nuclear power plant	305	25	^***	3 x R-13, since 1964 R-21	8
("Hotel-1")	1960	6000		22000			533		
"Navaga"	1967	8000	130.0x12.0x9.0	nuclear power plant	400	thirty	6	16 x R-27	34
("Yankee-1")	1968	9600		35000			533		

				plant					
("Delta-1"*)	1973	11750		60000			533		
"Murena-M"	1973	10500	155.0x12.0x10.0	nuclear power plant	400	25	6	16 x RSM-40	4
("Delta-2")	1974	12750		60000			533		
"Squid"	1976	10800	155.0X12.0X10.5	nuclear power plant	400	25	6	16 x RSM-50	14
("Delta-3")	1977	13250		60000			533		
"Typhoon"	1982	20000	170.0x24.7x11.5	nuclear power plant	400	29	8	20 x RSM-52	6
("Typhoon")	1983	25000		80000			533		
"Dolphin"	1985	11200	160.0X12.0X11.0	nuclear power plant	400	25	6	16 x RSM-54	7
("Delta-4")	1986	14500		60000			533		

** - the number of submarines of this type under construction;*
*** — the designation adopted in the USA and NATO is given in brackets;*
**** - 4 stern torpedo tubes of 356 mm caliber are also installed.*

Appendix 3
Performance characteristics of ballistic missiles

1. Medium-range ballistic missiles

BRSD R-5M (USSR). Created under the leadership of S.P. Korolev. Single-stage with liquid propellant rocket engine. Fuel: oxidizer - liquid oxygen, fuel - ethyl alcohol. The thrust of the RD-103 rocket engine on the ground is 41 tons. The control system is autonomous with lateral radio correction. Pre-launch preparation time for launch is about 2 hours. Length - 20.8 m, maximum diameter - 1.65 m. Starting weight - 29 tons. Maximum firing range - 1200 km. The warhead is a monoblock nuclear power plant with a power of 300 kt, a CEP of 3700 m. The missile was launched from a launch pad. Was in service from July 1956 to 1961.

IRBM "Jupiter" (USA). Testing began in the fall of 1956, and was put into service in the summer of 1958. Single-stage with liquid rocket engine. Fuel: oxidizer - liquid oxygen, fuel - kerosene. The control system is inertial. Length - 18.3 m, maximum diameter - 2.69 m. Starting weight - 49.9 tons. Maximum firing range - 3180 km. The warhead is a single-block nuclear power plant with a capacity of 1 Mt, CEP - 3600 m. It was launched from a ground launcher. Technical readiness for start - 15 minutes. Liquidated in 1965.

IRBM "Thor" (USA). Testing began on January 25, 1957, and was put into service in the summer of 1958. Single-stage with liquid propellant rocket engine. Fuel: oxidizer - liquid oxygen, fuel - kerosene. The control system is inertial. Length - 19.8 m, maximum diameter - 2.44 m. Starting weight - 47.6 tons. Maximum firing range - 3180 km. MS - monoblock nuclear power of 1.5 Mt or 3 Mt, CEP - 3200 m. Launched from a ground launcher. Technical readiness for start - 15 minutes. Liquidated in 1965. A total of 60 missiles were built.

BRSD R-12 (USSR). Chief designer M.K. Yangel. The first test launch took place on June 22, 1957. Entered service on March 4, 1959. Single-stage with liquid propellant rocket engine. Two-component fuel. The control system is inertial. Length - 22.77 m, maximum diameter - 1.65 m. Starting weight 42.2 tons. Maximum firing range - 2000 km. The warhead is a monoblock nuclear power plant with a capacity of 1 Mt, CEP - 2300 m. It was launched from the launch pad. Technical readiness for start 2 hours. R-12U - silo version, adopted for service in 1963. Liquidated in 1990.

BRSD R-14 (USSR). Chief designer M.K. Yangel. The first test launch took place in July 1960. Entered service in April 1961. Single-stage with liquid propellant rocket engine. Fuel: oxidizer - nitric acid, fuel - UDMH. The control system is inertial. Length - 24.3 m, maximum diameter - 2.4 m. Starting weight - 78 tons. Maximum firing range - 4000 km. The warhead is a monoblock nuclear power plant with a power of 1 Mt, a coefficient of propulsion of 1900 m. It was launched from a launch pad. Technical readiness for start 2 hours. R-14U - silo version, adopted for service in 1963. Liquidated in 1990.

IRBM "Dong-1" (China). Entered service in 1970. Single-stage with liquid propellant rocket engine. Fuel: oxidizer - nitric acid, fuel - kerosene. The control system is inertial. Length - 20.8 m, maximum diameter - 1.6 m. Starting weight - 50 tons. Maximum firing range - 2000 km. MS - monoblock nuclear power initially 20 kt, later - 700 kt, CEP - 3200 m. Launched from a launch pad. Technical readiness for launch - 2.5 hours. Removed from service in the mid-80s.

IRBM S-2 (France). The first test launch took place in May 1969. Entered service in 1971. Two-stage with engines running on mixed solid fuel. The control system is inertial. Length - 14.8 m, maximum diameter - 1.5 m. Starting weight - 31.9 tons. Maximum firing range - 3000 km. MS - monoblock nuclear power of 150 kt, CEP - 1000 m. It was based in a silo. Technical readiness for start 30 seconds. Was in service until 1982.

3700 km. The warhead is a monoblock nuclear power plant with a capacity of 1.2 Mt, CEP - 700 m. It is based in a silo. Technical readiness for start 30 seconds. It is in service.

IRBM "Dong-2" (China). The designation adopted by the PLA is "Dongfeng-3". The first test launch took place in 1971. Entered service in 1975. Single-stage with liquid propellant rocket engine. Fuel: oxidizer - nitric acid, fuel - UDMH. The control system is inertial. Length - 19 m, maximum diameter - 2.4 m. Starting weight - 70 tons. Maximum firing range - 4000 km. The warhead is a monoblock nuclear power plant with a power of 700 kt, a CEP of 2500 m. It was launched from a ground-based launch device or from a silo. Technical readiness for launch of an unfuelled rocket is 2.5 hours, a fueled rocket is 15–30 minutes. Removed from service in the mid-90s.

IRBM "Dong-2-1" (China). The designation adopted by the PLA is "Dongfeng-4". Entered service in 1977. Two-stage with liquid rocket engine. Fuel: oxidizer - nitric acid, fuel - UDMH. The control system is inertial. Length - 25.5 m, maximum diameter - 2.4 m. Starting weight - 110 tons. Maximum firing range - 6000 km. The warhead is a monoblock nuclear power plant with a capacity of 2 Mt, CEP - 3500 m. Launched from a ground launch device. Technical readiness for launch of an unfuelled rocket is 2.5 hours, a fueled rocket is 15–30 minutes. It is in service.

IRBM "Pioneer" (USSR). Chief designer A.D. Nadiradze. The first test launch took place in September 1974. Entered service in March 1976. Two-stage with engines running on mixed solid fuel. The control system is inertial. Length - 16.4 m, maximum diameter - 1.8 m. Starting weight - 37.1 tons. Maximum firing range - 5000 km. The warhead is a multiple warhead of the MIRV type with 3 warheads with a capacity of 150 kt each, KVO - 550 m. It was launched from a self-propelled launcher. Technical readiness for start 30 seconds. Liquidated in 1991.

IRBM "Pioneer UTTH" (USSR). Chief designer A.D. Nadiradze. The first test launch took place in August 1979. Entered service in December 1980. Two-stage with engines running on mixed solid fuel. The control system is inertial. Length - 16.4 m, maximum diameter - 1.8 m. Starting weight - 37.1 tons. Maximum firing range - 5500 km. The warhead is a multiple warhead of the MIRV type with 3 warheads with a capacity of 150 kt, KVO-450 m. It was launched from a self-propelled launcher. Technical readiness for start 30 seconds. Liquidated in 1991.

IRBM "Pershing-2" (USA). Tests began on July 22, 1982, and entered service in 1983. Two-stage with engines running on mixed solid fuel. The control system is inertial with correction of the warhead flight according to a radar map of the area. Length - 10.5 m, maximum diameter - 1.02 m. Starting weight - 7.4 tons. Maximum firing range - 2500 km. Warhead - monoblock nuclear with variable power: 0.3, 2, 10, 80 kt, CEP - 30 m. Launched from a mobile launcher. Technical readiness for start - 30 seconds. Liquidated in 1991. A total of 120 missiles were built.

2. Intercontinental ballistic missiles

ICBM R-7 (USSR). Chief designer S.P. Korolev. The first test launch took place on July 12, 1957. Entered service in January 1960. Two-stage, assembled according to a package design, with a liquid-propellant rocket engine. Fuel: oxidizer - liquid oxygen, fuel - kerosene. The control system is inertial with radio correction. Length - 27 m, maximum diameter: first stage - 3 m, second stage - 2.7 m. Starting weight - 283 tons. Maximum firing range - 8500 km. The warhead is a monoblock nuclear power plant with a capacity of 5 Mt, CEP - 2000 m. Technical readiness for launch - 2 hours. Launched from a ground launch device. Removed from service in the mid-60s.

Its modification **R-7A** was put into service in September 1960. It was distinguished by an increased length of the second stage, which made it possible to achieve a flight range of 9000 km. Length - 28.7 m. Starting weight - 285 tons. Removed from service in the mid-60s.

ICBM HGM-16 "Atlas-D" (USA). The lead developer is Convair. The first test launch took place on April 14, 1958. Entered service in 1959. Two-stage with liquid rocket engine, made according to a package design. Fuel: oxidizer - liquid oxygen, fuel - kerosene. The control system is inertial. Length - 25.2 m, maximum diameter - 4.8 m. Starting weight - 119 tons. Maximum firing range - 16,000 km. The warhead is a monoblock nuclear Mk4 with a power of 3-4 Mt, CEP - 3200 m. Technical readiness for launch - 15 minutes. It was launched from a ground launcher located in a reinforced concrete hangar. Withdrawn from service in 1964.

Modifications: **Atlas-E.** Entered service in 1962. It differed in the shape of the bow and the composition of the equipment. It was launched from a ground launcher located in a reinforced concrete semi-underground hangar. Technical readiness for start - 8-10 minutes. Withdrawn from service in 1964. **"Atlas-F".** Entered service in 1962. The main difference is in the basing method. The launching device was placed in the shaft and raised to the surface before the launch. Technical readiness for start - 10–13 minutes. Withdrawn from service in 1965.

ICBM LGM-25A "Titan-1" (USA). The lead developer is the Martin company. The first test launch took place on August 14, 1959. Entered service in 1961. Two-stage with liquid rocket engine, made according to the "tandem" scheme. Fuel: oxidizer - liquid oxygen, fuel - kerosene. The control system is combined inertial with radio correction. Length - 29.87 m, maximum diameter - 3.05 m. Starting weight - 98.5 tons. Maximum firing range - 10,400 km. The warhead is a monoblock nuclear Mk4 with a power of 4–7 Mt, CEP - 1700 m. Technical readiness for launch - 15 minutes. The launching device was placed in the shaft and raised to the surface before the launch. Removed from service in 1965.

ICBM R-16 (USSR). Chief designer M.K. Yangel. The first test launch took place in February 1961. Entered service at the end of 1961. Two-stage with liquid rocket engine, assembled according to the "tandem" scheme. Fuel: oxidizer - nitrogen tetroxide, fuel - UDMH. The control system is inertial. Length - 30.4 m, maximum diameter: first stage - 3.0 m, second stage - 2.7 m. Starting weight - 148 tons. Maximum firing range - 12500 km. The warhead is a single-block nuclear power plant with a capacity of 3 or 6 Mt, CEP - 2700 m. It was launched from a ground launcher. Removed from service by 1974.

Its modification **R-16U** is a silo version. The first test launch took place in January 1962. Entered service at the end of 1963. Removed from service in the mid-70s.

ICBM LGM-30A "Minuteman-1A(B)" (USA). The lead developer is Boeing. The first test launch took place in February 1961 (spring 1962). Entered service at the end of 1962 (late 1963). Three-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 16.37 m (17.05 m), maximum diameter: first stage - 1.68 m, second stage - 1.12 m, third stage - 0.94 m. Starting weight - 29.5 (31.3) t. Maximum firing range - 9250 (10200) km. Warhead - monoblock nuclear Mk5 with a power of 0.5 Mt (Mk11 with a power of 1 Mt), CEP - 1600 m. Technical readiness for launch - 32 seconds. Placed and launched from a silo. Removed from service in 1966 (1970).

inertial with radio correction. Length - 24.19 m, maximum diameter - 2.68 m. Starting weight - 80 tons. Maximum firing range - 13500 (12500) km. The warhead is a monoblock nuclear unit of two types: a standard one with a power of 3 Mt and a heavy one with a power of 4 Mt, KVO - 1600 m. Technical readiness for launch - 5 minutes. Placed and launched from a silo. Removed from service in the second half of the 70s.

ICBM LGM-25A "Titan-2" (USA). The lead developer is the Martin company. The first test launch took place in March 1962. Entered service in June 1963. Two-stage with liquid rocket engine, made according to the "tandem" scheme. Fuel: oxidizer - nitrogen tetroxide, fuel - aerozine-50. The control system is inertial. Length - 31.4 m, maximum diameter - 3.05 m. Starting weight - 150 tons. Maximum firing range - 10,200 km. MS is a monoblock nuclear MKB with a capacity of 10-15 Mt, KVO - 1500 m (after modernization of the SU-1100 m equipment). Technical readiness for start - 2 minutes. Placed and launched from a silo. Removed from service at the end of 1987.

ICBM LGM-30F "Minuteman-2" (USA). The lead developer is Boeing. Flight tests began in September 1964. Entered service at the end of 1965. Three-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 17.68 m, maximum diameter: first stage - 1.68 m, second stage - 1.39 m, third stage - 0.97 m. Starting weight - 32.7 tons. Maximum firing range - 11,500 km. The warhead is a monoblock nuclear Mk 11 V or C with a power of 1.5 Mt, KVO - 900 m, after modernization - 600 m. Technical readiness for launch - 32 seconds. Placed and launched from a silo. Withdrawn from service in 1994.

ICBM UR-100 (USSR). Chief designer V. N. Chelomey. The first test launch took place in April 1965. Entered service in the fall of 1966. Two-stage with liquid rocket engine, assembled according to the "tandem" scheme. Fuel: oxidizer - nitrogen tetroxide, fuel - UDMH. The control system is inertial. Length - 16.97 m, maximum diameter - 2.0 m. Starting weight - 50 tons. Maximum range - 10,000 km. The warhead is a single-block nuclear power plant with a capacity of 1 Mt, CEP - 1400 m. It was placed and launched from a silo. Removed from service in the mid-70s.

Modifications: **UR-10K (RS-10).** The first test launch took place in July 1969. Entered service in March 1971. Length - 18.95 m. Starting weight - 50.09 tons. Maximum firing range - 12,000 km. CEP - 900 m. Removed from combat duty in 1994. **UR-100U.** The first test launch took place in July 1971. Entered service in 1973. Length - 19.8 m. Starting weight - 51.24 tons. Maximum firing range - 10,000 km. The warhead is of a dissipative type with three warheads with a capacity of 350 kt, CEP - 900 m. Removed from combat duty at the end of 1994.

ICBM R-36 (USSR). Chief designer M.K. Yangel. The first test launch took place in September 1963. Entered service in July 1967. Two-stage with liquid rocket engine, assembled according to the "tandem" scheme. Fuel: oxidizer - nitrogen tetroxide, fuel - UDMH. The control system is inertial. Length - 32.2 m, maximum diameter - 3.0 m. Starting weight - 183 tons. Maximum firing range - 12,000 km. MS - monoblock thermonuclear with a capacity of 18 Mt or 25 Mt, CEP - 1200 m. It was placed and launched from a silo. Removed from service at the end of the 70s.

ICBM RS-12 (USSR). Chief designer S.P. Korolev. The first test launch took place in November 1966. Entered service in December 1968. Three-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 21.2 m, maximum diameter: first stage - 1.84 m, second stage - 1.49 m, third stage - 1.0 m. Starting weight - 51.5 tons. Maximum firing range - 9600 km. The warhead is a single-block nuclear power plant with a capacity of 0.6 Mt, CEP - 1900 m. It was placed and launched from a silo. Removed from service in 1976. The RS-12 was modified at the Sadovsky Design Bureau. Its first test launch took place in January 1970. Entered service in December 1972. Differences from the base model: Length - 21.35 m. Starting weight - 51 tons. Warhead - monoblock nuclear power 0.75 Mt, CEP - 1500 m. Removed from service at the end of 1994.

ICBM LGM-30G "Minuteman-3" (USA). The lead developer is Boeing. Flight tests began in August 1968. Entered service in 1970. Three-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 18.21 m, maximum diameter: first stage - 1.68 m, second stage - 1.39 m, third stage - 1.33 m. Starting weight - 35 tons. Maximum firing range - 10,000 km. The warhead is a multiplex nuclear Mk12 with 3 individually targeted warheads with a power of 330 kt each, CEP - 400 m, after modernization - 250 m. Technical readiness for launch - 32 seconds. Placed and launched from a silo. It is in service.

Modification - **"Minuteman-ZU".** Entered service in 1980. The maximum firing range is 9500 km. The warhead is a multiplex nuclear Mk12A with 3 individually targeted warheads with a power of 500 kt each, a CEP of 250 m. It is in service.

ICBM RS-20A (USSR). Chief designer V.F. Utkin. The first test launch took place in February 1973. Entered service on December 30, 1975. Two-stage with liquid rocket engine, assembled according to the "tandem" scheme. Fuel: oxidizer - nitrogen tetroxide, fuel - UDMH. The control system is inertial. Length - 33.6 m, maximum diameter - 3.0 m. Launch weight - 215 tons. Maximum firing range with a monoblock warhead - 10,500 km, with a MIRV - 9,250 km. The warhead is a monoblock nuclear warhead with a capacity of 24 Mt or a MIRV-type MIRV with 8 warheads with a power of 0.9 Mt each, KVO - 430 m. It was placed and launched from a silo. Replaced in the mid-80s by a modification of **the RS-20B.** Its first test launch took place in October 1977. Entered service in December 1980. Length - 35.7 m. Starting weight - 217 tons. Maximum firing range with a monoblock warhead - 16,000 km, with a MIRV - 11,000 km. The warhead is a monoblock nuclear warhead with a capacity of 20 Mt or a MIRV type MIRV with 10 warheads with a power of 0.5 Mt each.

ICBM RS-16A (USSR). Chief designer V.F. Utkin. The first test launch took place in December 1972. Entered service in December 1975. Two-stage with liquid rocket engine, assembled according to the "tandem" scheme. Fuel: oxidizer - nitrogen tetroxide, fuel - UDMH. The control system is inertial. Length - 22.5 m, maximum diameter of the first stage - 2.25 m, second stage - 2.1 m. Starting weight - 71.1 tons. Maximum firing range - 10,000 km. The warhead is a multiple warhead of the MIRV type with 4 warheads of 0.75 Mt each. CEP - 470 m. Placed and launched from a silo. Removed from service at the end of 1994.

Modification - **RS-16B.** The first test launch took place in October 1977. Entered service in December 1980. Starting weight - 72 tons. Warhead - multiple warhead of the MIRV type with six warheads of 0.75 Mt each, CEP - 350 m. Removed from service in the early 90s.

ICBM UR-100N (USSR). Chief designer V. N. Chelomey. The first test launch took place in April 1973. Entered service in December 1975. Two-stage with liquid rocket engine, assembled according to the "tandem" scheme. Fuel: oxidizer - nitrogen tetroxide, fuel - UDMH. The control system is inertial. Length - 24 m, maximum diameter - 2.5 m. Starting weight - 103 tons. Maximum range - 9650 km. The warhead is a multiple warhead of the MIRV type with six warheads of 0.75 Mt each, CEP - 350 m. It was placed and launched from a silo. Replaced in the early 80s by **the UR-100NU** by bringing the characteristics to new performance characteristics after replacing part of the equipment. The first test launch of its modification took place on October 26, 1977. Entered service on November 5, 1979. Differences from the base model: Length - 24.3 m. Starting weight - 103.4 tons. Maximum firing range - 10,000 km. It is in service.

ICBM "Dong-3" (China). Flight tests began in the late 70s. Entered service in 1983. Two-stage with liquid rocket engine, assembled according to the "tandem" scheme. Fuel: oxidizer - nitric acid, fuel - UDMH. The control system is inertial. Length - 33 m, maximum diameter -

Modification: **"Dun-ZM".** Adopted into service in 1993. The maximum firing range is 11,000 km, the warhead is a multiple warhead of the MIRV type with 4–5 warheads of 350 kt each, a CEP is 1,500 m. It is in service.

LGM-118A Peacekeeper ICBM (USA). The lead developer is Martin Marietta. The first test launch took place in June 1983. Entered service in 1983. Three-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 21.5 m, maximum diameter - 2.34 m. Starting weight - 88 tons. Maximum firing range - 10,000 km. Warhead - multiple MK21 type MIRV with 10 warheads with a capacity of 600 kt each, CEP - 100 m. Technical readiness for launch - 30 seconds. Placed and launched from a silo. It is in service.

3. Submarine ballistic missiles

SLBM "Polaris - A1" (USA). The lead developer is Lockheed. Testing began in September 1958. Entered service in September 1960. Two-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 8.68 m, maximum diameter - 1.37 m. Starting weight - 13.66 tons. Maximum firing range - 2200 km. MS - Mk1 nuclear single-block with a capacity of 0.5 Mt, CEP - 3700 m. Launched from a depth of no more than 25 m. Carrier - SSBN of the "J. Washington" with 16 missiles. Withdrawn from service in 1966.

SLBM R-11FM (USSR). Chief designer S.P. Korolev. The first test launch took place in September 1955. Entered service in February 1959. Single-stage with liquid propellant rocket engine. Fuel: oxidizer - nitric acid, fuel - kerosene. The control system is inertial. Length - 10.4 m, maximum diameter - 0.88 m. Starting weight - 5.4 tons. Maximum firing range - 160 km. The warhead is a single-block nuclear power plant with a power of 0.5 Mt, CEP - 7000 m. It was launched only from the surface position. The carrier is a submarine of project 611AB and 629. It was withdrawn from service in the late 60s.

SLBM R-13 (USSR). Chief designer V.P. Makeev. Entered service in October 1960. Single-stage with liquid propellant rocket engine. Fuel: oxidizer - nitric acid, fuel kerosene. The control system is inertial. Length - 11.8 m, maximum diameter - 1.3 m. Starting weight - 13.7 tons. Maximum firing range - 650 km. The warhead is a single-block nuclear power plant with a capacity of 1 Mt, CEP - 4000 m. It was launched only from the surface position. Carrier: Project 629 submarine and Project 658 submarine. Removed from service in the late 60s.

SLBM "Polaris-A2" (USA). The lead developer is Lockheed. Testing began in November 1960. Entered service in September 1962. Two-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 9.47 m, maximum diameter - 1.37 m. Starting weight - 14.7 tons. Maximum firing range - 2800 km. The warhead is a monoblock nuclear Mk1 with a power of 0.5 Mt or Mk2 with a power of 1 Mt, KVO - 3700 m. Launched from a depth of no more than 25 m. Carriers - SSBNs of the "J. Washington", "Ethen Allen", "Lafayette". Removed from service in 1976.

SLBM R-21 (USSR). Chief designer V.P. Makeev. Entered service in May 1963. Single-stage with liquid propellant rocket engine. Two-component fuel. The control system is inertial. Length - 12.9 m, maximum diameter - 1.4 m. Starting weight - 16.6 tons. Maximum firing range - 1300 (1600) km. MS - monoblock nuclear power of 1 Mt or 0.8 Mt, CEP - 2800 m. Launched from an underwater position. Carrier: Project 629A submarine and Project 658 submarine. Removed from service at the end of 1989.

SLBM "Polaris-AZ" (USA). The lead developer is Lockheed. Testing began in August 1962. Entered service in July 1963. Two-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 9.85 m, maximum diameter - 1.37 m. Starting weight - 16.13 tons. Maximum firing range - 4600 km. The warhead is a single-block nuclear Mk2 with a capacity of 1 Mt, KVO - 2300 m. Launched from a depth of no more than 25 m. Carriers - SSBNs of the "J. Washington", "Ethen Allen", "Lafayette".

Modification **"Polaris-AZT".** Entered service in 1968. Length - 9.65 m. Launch weight - 16.85 tons. Warhead - MkZ type with 3 dispersible warheads with a capacity of 200 kt each, CEP - 1000 m. Carrier - SSBN of the "J. Washington", "Ethen Allen", "Lafayette" (all USA) and "Resolution" (UK).

SLBM R-27 (USSR). Chief designer V.P. Makeev. Entered service in March 1968. Single-stage with liquid propellant rocket engine. Two-component fuel. The control system is inertial. Length - 9.65 m, maximum diameter - 1.5 m. Starting weight - 14.2 tons. Maximum firing range - 2400 km. The warhead is a single-block nuclear power plant with a capacity of 1 Mt, CEP - 1900 m. It was launched from an underwater position. The carrier is a Navaga-class SSBN.

Modifications: **R-27U.** Entered service in 1973. The maximum firing range is 3000 km, the COE is 1300 m. R-27U with a dispersible MIRV with two nuclear warheads with a yield of 200 kt each. Entered service in 1974. The carrier is a Navaga-class SSBN. All missiles were withdrawn from service at the end of 1994.

SLBM "Poseidon-SZ" (USA). The lead developer is Lockheed. Testing began in August 1966. Entered service in 1971. Two-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 10.36 m, maximum diameter - 1.88 m. Starting weight - 29.5 tons. Maximum firing range - 4600 (5600) km. The warhead is a multiple warhead of the MIRV type, it could be equipped with 10 or 6 nuclear warheads with a capacity of 0.05 Mt each, CEP - 800 m, after modernization - 470 m. It was launched from a depth of 25 m. The carrier was a Lafayette-class SSBN. Since 1993 it has been withdrawn from service.

SLBM M-1 (France). Entered service in 1970. Two-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 10.4 m, maximum diameter - 1.5 m. Starting weight - 18 tons. Maximum firing range - 2600 km. The warhead is a monoblock nuclear power plant with a capacity of 0.5 Mt, a CEP of 2300 m. It was launched from a depth of 25 m. The carriers were the Redoutable and Terrible SSBNs. Removed from service in 1976.

SLBM M-2 (France). Entered service in 1974. Two-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 10.7 m, maximum diameter - 1.5 m. Starting weight - 17.77 tons. Maximum firing range - 3200 km. The warhead is a monoblock nuclear power plant with a capacity of 0.5 Mt, a CEP of 2000 m. It was launched from a depth of 25 m. The carrier was the Fudroyant SSBN. Removed from service in 1979.

SLBM RSM-40 (USSR). Chief designer V.P. Makeev. Entered service in 1973. Two-stage with liquid rocket engine. Two-component fuel. The control system is inertial with astro correction. Length - 13.9 m, maximum diameter - 1.8 m. Starting weight - 33.3 tons. Maximum firing range - 7800 km. The warhead is a single-block nuclear power plant with a capacity of 1 Mt, CEP - 1500 m. It was launched from an underwater

SLBM R-31 (USSR). Chief designer V.P. Makeev. Entered service in 1980. Two-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 11.06 m, maximum diameter - 1.54 m. Starting weight - 26.9 tons. Maximum firing range - 3900 km. MS - monoblock nuclear power of 0.5 Mt, CEP - 1400 m. Launched from an underwater position. The carrier is a Navaga-M type SSBN. Removed from service at the end of 1991.

SLBM M-20 (France). Entered service in 1976. Two-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 10.4 m, maximum diameter - 1.5 m. Starting weight - 19.8 tons. Maximum firing range - 3200 km. The warhead is a monoblock thermonuclear unit with a power of 1 Mt, a CEP of 900 m. It was launched from a depth of 25 m. The carrier was a Redoutable-class SSBN. It is in service.

SLBM RSM-50 (USSR). Chief designer V.P. Makeev. Entered service in 1977. Two-stage with liquid rocket engine. Two-component fuel. The control system is inertial with astro correction. Length - 14.6 m, maximum diameter - 1.8 m. Starting weight - 35.3 tons. Maximum firing range - 6500 km. The warhead is a multiple warhead of the MIRV type with three warheads with a capacity of 0.5 Mt each, CEP - 900 m. It was launched from an underwater position. **Modifications** : one of them was put into service in 1978. The maximum firing range is 8000 km, the warhead is a monoblock nuclear warhead with a power of 450 kt. The other was put into service in 1978. It was equipped with a MIRV-type MIRV with seven warheads with a capacity of 100 kt each. Carriers are Kalmar-class SSBNs.

SLBM "Trident-C4" (USA). The lead developer is Lockheed. Testing began in January 1978. Entered service in 1979. Three-stage with rocket engines running on mixed solid fuel. The control system is inertial with astro correction. CEP - 300 m. Length - 10.4 m, maximum diameter - 1.88 m. Starting weight - 32.3 tons. Maximum firing range - 8000 km. The warhead is a multiplex MK4 MIRV type with eight nuclear warheads with a yield of 100–150 kt each. Can be launched from a depth of 30 m. The carrier is a Lafayette and Ohio class SSBN.

SLBM RSM-52 (USSR). Chief designer V.P. Makeev. Entered service in 1983. Three-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 16 m, maximum diameter - 2.4 m. Starting weight - 84 tons. Maximum firing range - 8300 km. The warhead is a multiple warhead of the MIRV type with 10 warheads with a yield of 100 kt each, a CEP of 500 m. It was launched from an underwater position. Carriers are Typhoon-class SSBNs. It is in service.

SLBM "Polaris - AZTK" (Great Britain together with the USA). Flight tests began in September 1977. Entered service at the end of 1980. Two-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 9.55 m, maximum diameter - 1.37 m. Starting weight - 16.5 tons. Maximum firing range - 3500 km. The warhead is a multiple warhead of the MIRV type with six nuclear warheads with a yield of 50 kt each, a COP of 500 m. It can be launched from a depth of 35 m. The carriers are SSBNs of the "Resolution" type.

SLBM M-4 (France). Flight tests began in November 1980. Entered service at the end of 1984. Three-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 11.05 m, maximum diameter - 1.93 m. Starting weight - 35 tons. Maximum firing range - 4500 km. The warhead is a multiplexable warhead of the MIRV type with six nuclear warheads with a capacity of 150 kt each, a CEP of 450 m. It is launched from a depth of 25 m. The carrier is the SSBN "Enflexible" and "Redoutable".

Modification: **M-45.** Will be put into service in the near future. Its maximum firing range is 6000 km. CEP - 400 m, Carrier - Triumphant-class SSBN.

SLBM RSM-54 (USSR). Chief designer V.P. Makeev. Entered service in 1986. Three-stage with liquid rocket engine. Two-component fuel. The control system is inertial with astro correction. Length - 15.3 m, maximum diameter - 1.9 m. Starting weight - 40.3 tons. Maximum firing range - 8300 km. The warhead is a multiple warhead of the MIRV type with four nuclear warheads with a power of 100 kt each, a CEP of 500 m. It is launched from an underwater position. Carriers are Dolphin-class SSBNs.

SLBM "Juylang-1" (China). Flight tests began in 1985. Entered service in September 1988. Two-stage with rocket engines running on mixed solid fuel. The control system is inertial. Length - 9.8 m, maximum diameter - 1.35 m. Starting weight - 13.8 tons. Maximum firing range - 2000 km. The warhead is a single-block nuclear power unit with a capacity of 0.35 - 0.5 Mt, CEP - 1300 m. It can be launched from depths of up to 25 m. The carrier is the Xia SSBN.

SLBM "Trident-B5" (USA). The lead developer is Lockheed. Testing began in January 1987. Adopted into service in 1990. Three-stage with rocket engines running on mixed solid fuel. The control system is inertial with astro correction. Length - 13.5 m, maximum diameter - 2.1 m. Starting weight - 57.7 tons. Maximum firing range - 10200 km, warhead - multiple MK5 MIRV type with 8 nuclear warheads with a yield of 475 kt each or 14 - with 100 kt each, KVO - 120 m. Can be launched from depths up to 45 m. Carriers are Ohio-class SSBNs.

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